THE

STAMP MILLING OF GOLD ORES

BY

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SECOND EDITION.

NEW YORK AND LONDON:
THE SCIENTIFIC PUBLISHING CO.,
1898.

THIS BOOK IS DEDICATED

TO

RICHARD PEARCE

AS A TOKEN OF RESPECT FROM

THE AUTHOR.

Gift
Mrs N M Langdon
12-13-27

PREFACE.

This book offers a careful description of the milling practice of gold-mining districts on both sides of the equator. It records the results of investigations made by the author in the course of professional work during the past ten years, and is published with the hope that the data which it contains may prove of service to comrades in the same field of industrial endeavor.

The author's inquiry into the principles of this important branch of metallurgy sprang from the first observation of the apparently contradictory practice of Colorado and California, in both of which states (during the years between 1885 and 1888) he had charge of the operation of typical milling plants. The search for the scientific principles explaining methods so diverse led him to the general study of the reduction of gold ores, and induced him to spread the inquiry over a field nearly commensurate with existing mining regions.

The matter thus collected is rather a painstaking description of practice than a discussion of the chemistry and mechanics of the stamp-milling process. It will, therefore, it is believed, be serviceable to those engaged in the actual work of the mill, no less than to the student in the laboratory or lecture-room.

The ordinary operations of the stamp mill do not involve a knowledge of nice chemical formulæ nor intricate mechanics. A good millman has the clarified common sense which lies at the basis of all true science, and has won a knowledge of the bed-rock principles of this ancient process of gold extraction such as no book learning can equal. To him the author has talked, and with him he has worked. To him he now humbly commends this book with the wish that the millman may

never do a thing without a reason for it, and always remember that where so great improvement has been made much more must yet be possible.

To the student starting out in his career as mining engineer or metallurgist, the author trusts the information gathered by a comrade, not much his senior, will be serviceable in emphasizing the many-sidedness of the stamp mill, and in awakening an intelligent interest in a process whose history covers the evolution of a great industry. To those about to choose a specialty in metallurgy, a science now covering a field so extensive as to be in its completeness beyond the mastery of any individual, he suggests gold milling as a profitable and fascinating study.

To the juniors in the profession the author would like to say that the gathering of correct information is a work which brings its own reward. The publication of data thus collected may not be of much moment to this busy world, but it clarifies the contributor's ideas and gives a compact crystalline form to a quantity of amorphous knowledge, rendering the routine work of the profession vastly more productive and pleasant. There is no better way of winning knowledge than to give away the little that you have; all that we all of us know is but a small matter. The worst of all waste is the waste of experience.

Such have been the feelings that prompted the making of this book, and with such the writer offers it now to his fellow workers.

T. A. RICKARD.

DENVER, COL., January, 1897

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

CHAPTER I.

The Philosophy of the Stamp-Milling Process.

Milling is a process of ore reduction whereby the extraction of the valuable metals is effected at a minimum of expense. Gold stamp milling is that particular process in which a heavy cylindrical body of iron is made to fall upon the ore in such a manner as to crush it, and thereby facilitate a separation between the gold and the valueless minerals by which the gold is encased. The latter weigh less than the former, and are removed by the aid of water. The gold is then collected through the agency of mercury with which it readily forms an alloy or amalgam. From this combination it is finally extracted by the distillation or retorting of the mercury.

The mechanism of the stamp acts on principles similar to those underlying the crudest devices used by man. It may be likened to a hammer, of which the shoe is the hammer head, the stamp stem is the handle, and the die the anvil. The ore itself has been compared to a nut struck by a hammer whose blow has separated the valueless shell (the quartz) from the valuable kernel (the gold). Similes such as these may be carried further. The hammer falls, the anvil is fixed; the same relation exists between the stamp and the die inside the mortar. The anvil is made of softer metal than the hammer, so also the die is often, and should be always, of iron or steel less hard and more tough than that composing the shoe. The movement of the hammer and the drop of the stamp are both intermittent. There is in both a loss of power due to inelastic impact; in both, also, there is an apparent loss of time due to the interval separating the blows. In the case of the hammer that interval of time is utilized in the shifting of the material which the hammer blows are shaping; in the case of the

stamp the time is turned to advantage in the opportunity which it gives for the water to assist in the separation of the gold from the quartz.

The hammer falls upon the dry and wide surface of an anvil, the stamp, however, drops upon a face of iron (the die) confined within a narrow box (the mortar). Water covers the die and the ore lying upon it. The blow of the falling stamp not only crushes the ore, but also causes a violent pulsation of the water. That pulsation becomes converted into an irregular splash against the sides of the mortar. The latter has an opening in front, through which the water is discharged, carrying with it the crushed ore. This, called the pulp, spreads itself over tables placed on an incline, which are lined with a metal, usually copper, having an amalgamated surface such as will arrest the particles of gold and at the same time permit the grains of quartz and other valueless material to pass over it and out of the mill.

The work done by the hammer is dependent upon its weight, the rapidity of its blow, and the distance through which it strikes. In stamp milling this simple analogy has many departures from it. These can best be explained by examining two extreme types, such, for instance, as are afforded by the divergent methods of Colorado and California.

If you go to Black Hawk, in Gilpin County, Colorado, and walk up the long straggling street, you will hear the stamps falling so slowly that the drop of individual ones can be distinguished. At one time the rate used to be about 24 per minute, now the speed is regulated at an average of 30 drops per minute. If, on the other hand, you should visit Angel's Camp, in Calaveras, or Sutter Creek, in Amador County, California, you would hear the muffled roar of stamps falling so fast as to make it quite impossible to recognize the drop of any single one. There the rate would average 90, with an occasional maximum of 105 drops per minute.

Upon further inquiry we shall find that in Colorado the stamp weighs 500 to 600 pounds, the most common figure at Black Hawk being 550. In California the extremes are greater, from 750 to 1000 pounds, with a frequent repetition of 850. In Colorado the drop ranges from 16 to 20 inches, in California from 4 to 6 inches. If we now multiply these three

factors of weight, drop and speed, we find that the theoretical work done is nearly equal and is approximately 1 horse-power. But the results aimed at in stamp milling cannot be measured in foot-pounds. The efficiency is gauged rather by the amount of ore crushed and the completeness wherewith the gold is extracted. The stamp mill is both a crushing machine and an amalgamating contrivance. Therefore, notwithstanding the approximate equality in the sum total of theoretical work, the Colorado mill crushes only one ton per 24 hours; while in California, with an ore of similar hardness, the amount is from two and one-half to three times as much. Why is this difference? Should it exist? Is it the result of ignorance or the outcome of experience? In answering these questions we shall have to discuss the bed-rock principles of stamp milling.

To the first question the answer comes promptly. The difference is due to the dissimilarity of the ores treated. That which goes to the mills at Black Hawk contains an average of 15 per cent. of pyrite. The gold which it carries is in a very fine state of subdivision, and is intimately associated with the pyrite. On the other hand, the mill stuff treated at Angel's Camp, or Sutter Creek, carries only from 1 per cent. to 2 per cent. of pyrite, and the accompanying gold is not nearly so intimately mingled with it, but rather occurs in clean quartz and in a comparatively coarse condition. The immediate result is that coarse crushing, which is, of course, more rapid and therefore more economical than fine crushing, will do for the California simple quartz ores what it can not do for Colorado's complex pyritic material.

Let us return for a moment to the simile of the hammer and the nut. The hammer which cracks open the nut may liberate the kernel without crushing it. I have seen gold-bearing quartz which could be likened to such a nut. The gold occurred in cavities in quartz of a honeycombed kind. In dealing with such an ore there is just a certain blow which will break the brittle quartz and liberate the ductile gold. Such conditions are ideal. Usually the hammer will not only break the shell but also crush the kernel, so that the particles of both become confused together. This more nearly resembles the ordinary action of the stamp, which has, moreover, to deal

with a material in which the gold and its envelopment of gangue, the valuable and the valueless constituents, are so irregular in size and so intermixed that the one is often crushed too much and the other too little.

Particles of gold will remain attached to or enveloped by pieces of quartz, rock, or pyrite, unless crushed to a fineness such as compels a separation. Without such a complete separation amalgamation will not take place. It is obvious, therefore, that when the gold in an ore is coarse the process of crushing need not be carried so far as when the gold is in a state of minute subdivision.* Again, it is evident that the longer a particle of ore remains inside the mortar the more frequently, other things being equal, will it undergo the blow of the stamp, and that the more often it is struck by the stamp the finer the condition into which it will be pulverized.

How are these factors regulated? In two ways, by the depth of discharge and by the mesh of the screen.

The ore upon the die is under water. After it has been sufficiently crushed it is ejected by the splash of the water through the screen or grating which covers the opening in the front of the mortar. The surface of the water is approximately level with the bottom of the aperture occupied by the screen. In Colorado the depth of discharge (also termed the issue), as measured by the distance from the bottom of the screen to the top of the die, is 14 inches. In California it is 4 inches only. Here we have found one of the reasons for the difference in the crushing capacity of the mills. Though the same amount of power be expended in lifting the stamps, and though the screen used be of a similar mesh, yet in Colorado less ore is crushed in a given time because the stamp falls through 10 inches more of water and has to eject the crushed ore at a level 10 inches higher than in the California mill. The greater thickness of the cushion of water deadens the blow of the stamp and weakens the force of the splash.

What is the result upon the ore? It is found that even with screens of equal mesh the crushed ore remains inside the deep

*Only microscopic examination can give one an adequate idea of the minuteness of the particles of gold in certain ores, or of the extent of its diffusion through the mass.

Colorado mortar longer than in the shallow one used in California, and that, therefore, the pulp discharged from the former has a fineness much greater than that delivered from the latter. The screen is a controlling, but by no means final, factor in regulating the rapidity of the discharge and the size of the particles of the pulp. In California 30-mesh wire cloth is ordinarily employed; in Colorado, slot-punched screens equivalent to 50 mesh. The one represents 900 and the other 2,500 holes per square inch. In neither case, however, is the ore crushed just to that particular size permitting of exit through the screen, but much of it is crushed to an unnecessary and far greater degree of fineness. It is found with the use of screens of similar mesh, say 40, that in a California battery about 50 per cent., and in a Colorado mill fully 70 per cent., of the pulp will pass through a 100-mesh sieve. This is due to the pause which occurs between the successive drops. Particles of ore which have been pulverized to a size which would allow of their discharge through the screen are enabled to fall back and are recrushed by the succeeding blows of the stamp. In the fast (California) mill the interval between the drops is two-thirds of a second; in the slow (Colorado) mill it is two seconds.

The irregular splash of the water inside the mortar causes an unequal sizing of the pulp. The particles of pulverized ore strike the screen in a haphazard way. It is a question of hit or miss whether any particular particle be thrown against an opening or a blank. If it fail to pass through, it is drawn back by the recession of the water and undergoes further pulverization. This action must obviously take place to a greater extent in a deep mortar with a punched screen which offers less opportunity for free discharge than in a shallow mortar with a wire screen which offers increased facility for the issue of the pulp. Hence the tendency to a greater degree of excessive pulverization in the Colorado mill as compared to the Californian.

This excessive pulverization is desired by the Colorado millman because it enables him to break the close intimacy between the finely divided gold and its associated pyrite. He therefore has combined the features of a long and slow drop with a deep discharge. The comparatively light weight of

the stamp is necessitated by the excessive height of the drop. He has also designed a mortar which is wide and roomy. This causes the splash of the water inside the battery to be weak, and compels the pulp to remain inside until pulverized to a fineness much exceeding that required merely for its passage through the screen openings. Then, having obtained conditions enabling him to separate the gold from the pyrite in the ore, he catches it upon amalgamated copper plates which are arranged along the front and back of the mortar. To sum up, he makes the crushing feature of his mill subservient to amalgamation. Now turn to the Californian. His ore does not require such fine pulverization, because it does not present such difficulties to the separation of the gold which it contains. He finds he can readily save the gold in the pulp, after it has been ejected from the battery, by catching it upon tables covered with amalgamated sheets of copper. He, therefore, has made his battery primarily a fast-crushing machine, and only incidentally an amalgamator. If gold is caught within the mortar, as some usually is, so much the better; but, I insist, amalgamation inside the battery is secondary to the obtaining of conditions facilitating rapid crushing. The Californian has consequently found that for his purpose the best arrangement is that of a stamp mill having heavy, fast dropping stamps which will induce rapid pulverization; he has designed a narrow mortar, thereby diminishing the opportunities for the resettling of particles of pulverized ore; he has utilized a shallow discharge, thereby increasing the force of the splash of the water and accelerating the exit of the pulp through the screen. In this case the introduction of plates for amalgamation is rarely admissible, because in mortars having so shallow a discharge as 4 inches, the violent agitation of the pulp abrades or scours the surface of such plates.

We have given the reason for the marked difference existing between the milling methods of two districts in the same country. Next comes the query, Should such a difference exist? Yes, if stamp milling is to be the process employed in the reduction of the ore. The first axiom of successful milling is that the process which is the best adapted to the ore and the cheapest under any given conditions is the one which

should be chosen. It has been claimed by many that the stamp mill is not the best machine, nor amalgamation the best process, for the treatment of the ores of Gilpin County, the home of the Colorado method which has been described. It has been stated that the practice which is in vogue there is incorrect from a metallurgical standpoint, and out of date. Concentration has been suggested as the proper process. The examination of this question is an excellent example of the relation existing between the commercial and technical sides of metallurgical practice.

Take, for instance, the case of 10 tons of ore, each carrying $8 worth of gold. The yield by amalgamation would be, say 65 per cent., equivalent to $52, to be supplemented by a further yield of 15 per cent., or $12, in the form of one ton of pyrites concentrates. There would thus be obtained $64 out of the original contents ($80) of the ore, equal to an extraction of 80 per cent. The ton of concentrates would be shipped to Denver, where the smelter would pay 95 per cent. of the assay value, less the charge for treatment, $5, and freight, $1.50. The net return would be $9.90. This last figure added to the gold obtained by amalgamation, which is usually sold to a local bank, gives $56.90 as the final return from the 10 tons of ore.

Now, suppose concentration to be substituted for the present method of milling. The 10 tons of millstuff would be concentrated into one. Supposing the extraction to be 80 per cent., then the one ton of concentrates would have an assay value of $64. When forwarded to the smelter this material would be required to pay a higher treatment charge because of its higher value and its greater silica contents. The charge would be from $8 to $10 per ton. Let us take the lower figure, $8, and add to it the freight, which would be $2, or 50 cents more than that levied on the lower grade material. Add $1 for sampling,* and the total deductions, the smelter paying 95 per cent. of the assay value, foot up to $14.20, leaving $49.80 as the final return. There is, therefore, a balance of $7.10 in favor of the present method.

In the above example the costs of milling and concentration

*Avoided in the case of the very low grade, finely pulverized and homogeneous stamp-mill concentrates which are hand-sampled by means of a tube resembling a cheese-taster.

have been supposed equal, and an extraction of 80 per cent. allowed in both cases. There are some ores in Gilpin County which, being more heavily charged with pyrites, galena, etc., are more suitable for concentration than stamp milling; similarly there are others so poor in pyrite and so free milling as to put concentration out of court. On the whole, however, the above-cited example will be sufficient to indicate how largely local commercial considerations enter into the choice of the method of ore reduction.

The last question which we set out to answer was whether the existing practice in Colorado and California is the result of ignorance or the outcome of experience. This has already been answered in the foregoing paragraphs. Nevertheless, a few additional notes may prove instructive.

In both cases, California and Colorado, the first methods adopted were derived from a common origin. They were brought westward by the pioneers who came from Georgia, and who had themselves in turn borrowed their ideas from the classic regions of Transylvania. In both cases the evolutionary changes of a local experience have gradually so modified the original method that the common parentage of the local practice is no longer evident to the investigator. On the Pacific coast the ore was found to be even more simple in character than that of Georgia; the methods first introduced were, therefore, modified in such a way as to increase the relative importance of the crushing capabilities of the stamp mill. The experience of the placer miner was allowed to influence the choice of the apparatus intended for the process of amalgamation. As a consequence the chemical side of the process has remained practically unchanged, while the crushing mechanism has been improved by a number of ingenious devices giving greater automatism in the handling of the ore.

In the Rocky Mountains of Colorado it was found that the mills erected by Gregory and the other Georgian pioneers did good work upon the simple surface quartz which was first discovered, but so soon as the unoxidized heavily pyritic ores of the deeper workings of the mines were encountered the extraction fell off woefully. The district was paralyzed. The smelter, with its process of fire reduction, came to the rescue.

Stamp milling became supplemented by smelting. At the same time battery amalgamation was found to be facilitated by deepening the discharge and widening the mortar. This was necessarily accompanied by a higher drop, which in turn prevented the use of very heavy stamps. Gradually the everyday experience of the millmen enabled them to arrive at the conditions most favorable to good work. The smelter also realized the value, for fluxing purposes, of the low-grade iron pyrites composing the mill concentrates, and so the practice of the camp was whittled into its present shape.

While, therefore, in Gilpin County a quite peculiar set of circumstances renders an apparently antiquated method of milling well adapted for the economical treatment of the ores of that particular district, nevertheless the unthinking imitation of this practice in other districts, working under dissimilar surroundings, is not to be commended. Elsewhere in the State of Colorado the Californian method has been found better suited to the cheap reduction of the ores, and it has been successfully adopted. On the other hand, conditions in certain parts of Montana and Arizona are such as occasionally to render slow, fine crushing, accompanied by battery amalgamation,* more desirable than either fast, coarse crushing without inside amalgamation† or straight out-and-out concentration. Science is only organized common sense; the most truly scientific method is necessarily the most sensible. It is the business of the millman to determine what are the exact conditions and then adapt his method to them. In California there are, for similar reasons, certain variations from the typical local method, such as indicate an approach toward the old Colorado practice. Thus, in Amador County, the depth of discharge has been deepened to seven or eight inches and an amalgamating copper plate is attached to the front inside of the mortar. The result is to lessen the rate of crushing, increase the fineness of pulverization, and augment the proportion of gold saving effected within the battery.

Milling is a matter of business. The closest application of technical science may occasionally be obtained at the expense of the best commercial results. Thus you may save 80 per

*Plus tables and supplementary concentration.

†But with amalgamating tables followed by Frue vanners.

cent. of the value in an ore at a cost of 80 cents per ton. By the use of further skill and added apparatus you may extract five per cent. more, but the value of that additional saving may be less than the extra expense, so that while you get $3.20 out of a $4 ore at a cost of 80 cents, you obtain $3.40 at a cost of over $1.10. Your additional 20 cents' worth of gold has cost more than 30 cents to obtain.

Metallurgy is an applied art. When employed in the practice of milling it should mean an extraction as large as is consistent with the least expense. Chemistry must be supplemented by common sense and mechanics by business insight. It is this effective combination which has given the western mining industry its prosperity and progressiveness.

CHAPTER II.

Gilpin County, Colorado.

Gilpin County, the most important gold mining-district of the State of Colorado, lies at the foot of the main range of the Rocky Mountains. With its record is interwoven the beginning of the history of Colorado and the birth of a great industry.

In the days when this part of the United States was yet a portion of Kansas, an unknown region overrun by the Indian and the now almost extinct buffalo, a motley crew of eager seekers after gold were drawn thither by the fame of Pike's Peak. The pioneers of 1858 were mostly Georgia men, some of whom had been to California. When their El Dorado proved a delusion, the more enterprising, leaving the log cabins by the side of the River Platte—log cabins which marked the site of the now stately city of Denver—followed the course of Clear Creek up the winding cañons and found the river gravel which produced the first output of gold. The alluvial deposits, however, owing to the narrow, rocky channel and the rapid current of the stream, were of but small extent, and the area available soon becoming exhausted necessitated the search for further gold-bearing ground. It was then that the pioneer, following the rapidly narrowing beds of the mountain torrents, found himself fronted by the ramparts of the mighty Rockies themselves, and turning to one side discovered in the quartz lodes the original source of the river gold.

In April, 1859, John H. Gregory first made his way up North Clear Creek and found good prospects near Black Hawk. On May 6 the Gregory lode was discovered. The fame of Gregory Diggings at once drew to it all the wandering population scattered among the neighboring hills. Other lodes were discovered in rapid succession. Then there commenced the

active working of the gold veins, which is the only excuse for the existence of Black Hawk, Central City, and Nevadaville; which for a long time made Gilpin County the chief gold producer of Colorado; which trained the men who opened up the Leadville mines, and gave the money to those who built up Denver.

While the area of Gilpin County is only 122 square miles, its output to date is estimated at $76,000,000. Its largest annual production (in 1889) was $3,334,300, while that for last year is estimated at $2,000,000.

As a milling center it ranks among the most important. The history of the evolution of the milling practice of Gilpin County forms one of the most interesting chapters in the record of the American mining industry. Briefly it was thus: The first machine introduced was the arastra, which at first proved satisfactory, but was soon found to be too slow for the American, however well suited to the Mexican. Stamp mills of three, four, and six heads were erected by the Georgian miners, and these in turn gave place to larger plants modeled after the California fashion. This type—fast drop and shallow discharge—of battery was adapted to the treatment of the surface quartz. All went well; the output and importance of the district steadily increased. In July, 1860, sixty mills were at work in the county. The gold saving at that time was all done by riffles, carrying quicksilver, but in the following year the first copper plates were introduced. Soon after this the camp received its first check; the oxidized material of the upper portions of the lodes began to give place to ore which was less quartzose, which contained more of the country rock as vein filling and carried a percentage of pyrites which steadily increased with depth. This was at levels varying from 100 to 200 feet. The mills which had previously been extracting from 60 per cent. to 75 per cent. of the gold contents, gradually commenced to return only 50 per cent., 40 per cent., and then 30 per cent. None but the richest ore would now pay; the mills swallowed up two-thirds of the yield which should have rewarded the miner's toil; some of the mines were forced to shut down, while others had to confine their development to the narrower, richer portions of the lodes. Gilpin County as a mining field seemed to be about

Central City and Black Hawk, Colorado.

to write "finis" across the portals of its mills and engine-houses. At this juncture a small smelting establishment was erected in the district, and the metallurgist came to the rescue of the baffled millman. It was in the spring of 1867 when the Boston & Colorado Smelting Works were first established at Black Hawk. The Swansea process of copper smelting was introduced, the matte being shipped East. In the year which followed most of the mills remained idle; many of the mines were shut down, for only those could afford to be worked which yielded ore sufficiently rich to meet the cost of smelting. For some years the smelter took the place of the stamp mill, but in the interval the energetic, resourceful men of the place studied the successful treatment of their pyritic ores, and after experiments, which cost much time and more money, eventually in the beginning of the "seventies" they solved one of the knottiest questions ever put to the miner.

We are now familiar with the terms "free milling" and "refractory" ore, and we are to some extent cognizant of the different treatment required by the two types, but such knowledge as we possess is in no small measure due to the plucky manner in which the millmen of that day overcame the obstacles presented by the treatment of a most difficult ore.

The accompanying tabulated statement illustrates how, from the Californian or "fast drop, shallow discharge" type of milling practice, Gilpin County has arrived at a distinct type which may be summarized in contrast as the "slow drop, deep discharge" system.

The figures herewith given will serve as a text for the paragraphs which follow.

One of the best mills of the district is the Hidden Treasure, the property of the California mine, and as it thoroughly represents the best practice of Gilpin County, I shall take it as a type and endeavor to describe fully the methods of work.

The Hidden Treasure plant consists of 75 stamps in three sections of equal number; of these two are of an older date than the third. The stamps of the former are supplied with screw tappets, while in the case of the latter the tappets are kept in place by means of gibs and keys. The last-mentioned method is much preferred.

The stamps weigh 550 pounds each and fall at the rate of from 30 to 32 drops per minute. The order of drop is 1-5-2-4-3.

COMPARATIVE TABLE OF GILPIN COUNTY MILLS.

Name of the mill.	Number of stamps.	Weight of each stamp; pounds.	Number of drop per minute.	Height of the drop; inches.	Depth of discharge or issue; inches.	Capacity per stamp head; tons.*	Capacity of entire mill; tons.	Size of the screen; number.	Description.	Percentage of concentrates per ton of ore; per cent.	Value of the concentrates per ton; dollars net.	Percentage of bullion obtained in retorting; per cent.	Fineness of bullion; per 1000.	Life of the screens; days.	Loss of mercury per ton of ore crushed; dwts.†	Consumption of water per stamp per min.; gallons.
Hidden Treasure,	75	550	30 to 32	16 to 18	13 to 15	1.14	85	1½	Burr slot, alternate punched.	13	15	40	782 to 786	81	4.3	2.0
Gregory Bobtail,	125	550	27 to 30	16 to 18	11 to 13	1.04	130	1 and 2		14	10 to 25	40	800 to 850	60	5.2	2.3
Randolph,	50	500	30	16 to 18	14 to 16	.93	48	1½		20	10	33 to 47	750 to 850	16	9.8	1.4
New York,	75	600	26	18 to 20	13 to 15	1.07	80	1½		15	7 to 10	40	750 to 800	25	3.7	1.3
Prize,	25	500	28 to 30	15 to 17	13 to 16	.80	20	1½		12	10 to 15	35	750 to 775	75	9.7	1.5

*Tons of 2,000 pounds each. †Mercury is sold by avoirdupois—a tank contains 76½ pounds.

Each stamp makes from 1¼ to 1½ revolutions with each drop, depending upon the amount of grease upon the cam surface.

Height of drop

Depth of discharge

The height of the drop varies from 16 to 18 inches. The issue or depth of discharge—that is, the distance from the top of the die to the bottom of the screen—is 13 inches when new dies have just been placed in position, and increases to a maximum of 15 and 15½ inches as they wear down.

Shoes Dies

The shoes are 5½ inches deep and 8 inches in diameter. The dies are plain, cylindrical in shape and fit into a round seat in the mortar bed. They are 3½ inches deep, slightly wider than the shoes, and are kept in place by sand which is packed tightly between and around them. The shoes weigh from 83 to 86 pounds each, the dies from 46 to 48 pounds; both are made of cast iron at the local foundries. The wear of the shoe is at the rate of 11.3 ounces of iron per ton of ore crushed, that of the dies is 4.5 ounces per ton.

Capacity

The capacity of the mill varies somewhat. At present 50 heads are engaging in treating custom* ore, and these crush faster than the 25 which are fed by millstuff coming from the California mine. The entire mill crushes 320 cords or 2,560 tons per month of 30 days. The mills do not close down on Sundays. From January to May, inclusive, 1,066.48 cords were crushed by the 50 heads. This, taking a cord as equal to 8 tons, comes to 1.14 tons per stamp per 24 hours.†

Screens

The screen used is that known as burr slot; the slots are horizontal and alternate. No. 1½ is generally employed, that size being equal to a 50-mesh wire screen. The screen surface is 4½ feet by 8 inches. During the past year 200 feet of screens were used up, or at the rate of 66.6 screens per year. The average life of a screen was therefore 81 days. With the ore coming from the California mine they last three months, it being the custom to turn the screen upside down as soon as the lower portion, the first affected, gets worn. Occasionally, after having served for the treatment of the company's ore, the screens are used in the custom sections of the mill

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* Custom milling is a great feature of the mills of this section. The charges are $7.50 per day per battery of five heads, this to include the concentration of the pyrites and their shipment on board the railway car. For small lots the rates are $15 per cord for milling and $2 per cord for concentrating. The last charge varies from $1 to $3, according to the percentage of pyrites in the ore.

† In this district there is a curious custom of measuring ore by the "cord," a unit derived from firewood measurement, and equal to 8x4x4 feet or 128 cubic feet. A cord of mill ore is equal to 7¼ to 8 tons, and one of smelting ore to from 9 to 10 tons

where coarser crushing is required by an ore coming from a shallower level and of a somewhat different character.

The average of a year's work shows that the ore yields concentrates at the rate of 13 per cent., and of a mean net value of $15 per ton. Both the quantity and quality of the concentrates vary directly with the richness of the millstuff.

Concentrate

In retorting, the percentage of bullion yielded by the amalgam varies from 30 to nearly 50 per cent., but 40 per cent. may be considered the average. The bullion contains 782 to 786 per thousand of gold and 207 to 211 of silver.

Bullion

Six and a half tanks of quicksilver are consumed by the 75 stamps in one year. This amounts to 4.3 dwts. per ton of ore crushed. The quantity of water used in the mill is at the rate of 2 gallons per stamp per minute.

Mercury Consumption

Water Consumption

The gold saving is done in the mortar boxes, on amalgamating tables, by the blankets, and finally by concentrators. The last mentioned were formerly supplemented by buddles or "tyes," but these have now been discarded. The mortar box itself does most of the work of arresting the gold. This is effected by the free mercury which is added, supplemented by two amalgamating plates arranged along the front and back of the mortar. They are both made of plain copper. The back plate is 12 inches wide and 4½ feet long. The front plate is of the same length, but has a width of only 6 inches. The two plates are arranged differently, that at the back being placed at an angle of 40 degrees, while the front one is nearly upright. At the front of the battery and above the screen frame there is an opening ordinarily covered by canvas, by the lifting of which the millman is able to introduce his arm and can tell by the feel of the front plate whether the correct quantity of mercury is being added by the feeder. The regulation of the addition of mercury is thus effected without the stoppage of the battery or the removal of the screen frame. Upon an average the feeder adds a half thimbleful of quicksilver every hour. As a test it was found that in crushing one cord (8 tons) of ore carrying gold at the rate of half an ounce per ton, there were added 4⅛ ounces of mercury, one drop as large as a medium-sized pea every hour after the first six hours.

Mortar Plates

Addition of Mercury

The amalgamating tables are of copper and are in one

length of 12 feet, having a breadth of 4 feet. They slope $2\frac{1}{8}$ inches per foot. In the crushing of three cords* of half ounce stuff (10 dwts. per ton) it was found that the one copper table used required 5 ounces of mercury to dress it, while there were used for the dressing of the front inside plate 3 ounces, and for the back or wide plate 4 ounces.

Blankets

The blanket strakes, or "blanket strips," are 3 feet long and 18 inches wide. They are washed three times per day or every four hours, an interval which, with rich ore, is decreased sometimes to two hours. They serve to arrest any escaping amalgam or mercury, as well as "rusty" gold and the heaviest pyrites, together with particles of ore to which gold is still attached. They may be perhaps needed to save the last-mentioned class of material, but for the rest the millman is probably correct in his belief that they could be discarded without any loss, since this work is done by the concentrating machines.

Concentrators

From the blankets the pulp passes to the concentrators, which are shaking tables, called in the locality, where they are also constructed, "bumpers." They are the outcome of Gilpin County practice, and are a variation of the Rittinger type; see illustration. In the Hidden Treasure mill there are five of these, each subdivided into two parts. The new model is of a lighter pattern than the old, which was divided into three partitions. The speed is regulated according to the percentage of pyrites in the ore, but will average at the rate of 130 strokes per minute.

Amalgam yield

Of the total amalgam obtained, two-thirds is the yield of the plates inside the mortar box, the amount being fairly divided between the two.† On cleaning up, the sand found in the battery around the dies is *not* panned but returned to the mortar on restarting. The outer amalgamating tables are cleaned up every 24 hours, but the inside plates only every 48 hours. With poor ore the last-mentioned period is further prolonged.

Clean up

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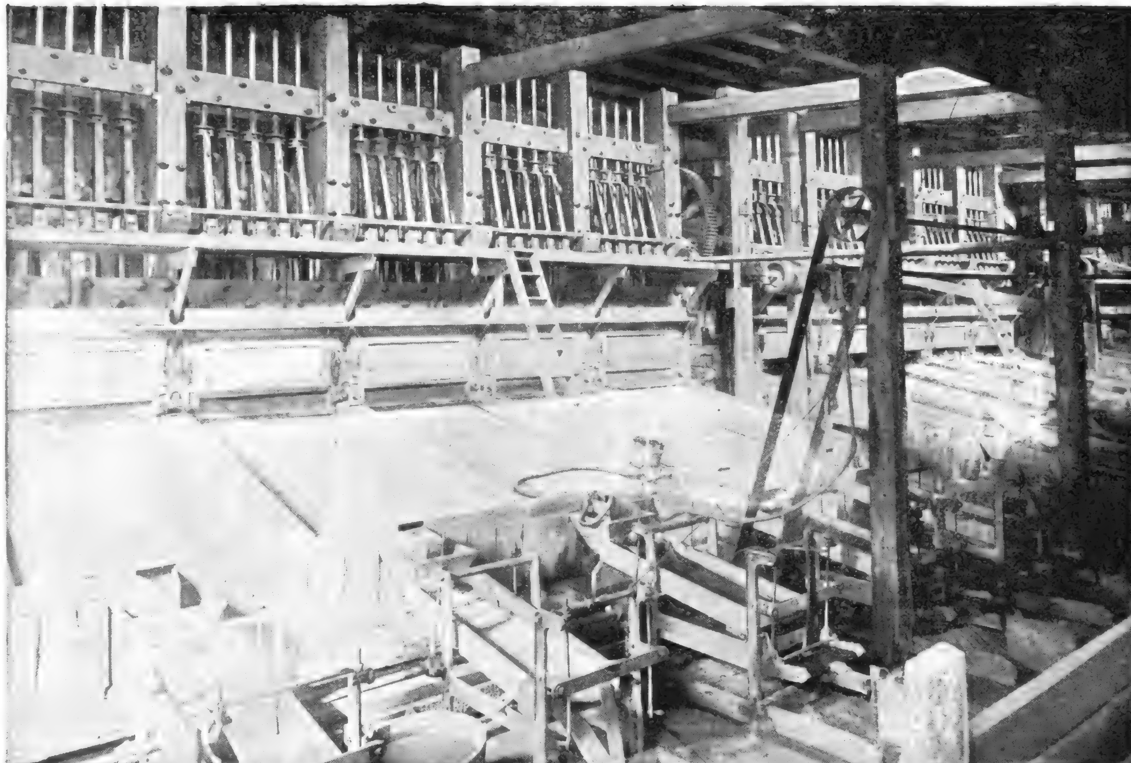
* A cord is the unit of firewood measurement. It consists of 128 cubic feet, equivalent, in the case of broken millstuff, to 8 tons.

† It is found, therefore, that the direct saving of the gold (the saving in the blanketings and concentrates is indirect) is evenly divided between the three amalgamating appliances—the front inside battery plate, the back inside plate, and the outside table.



Interior of the Hidden Treasure Mill, Black Hawk, Colorado.

Clean Up

At the general clean-up the amalgam, as it comes from the plates, is placed in a mortar to be ground, with the addition of hot water, until of even consistency. The now dirty water is decanted and mercury is added until the amalgam is thin. The thin-flowing amalgam (or, rather, mercury, which has absorbed the amalgam) is decanted from one porcelain dish to another several times. As the pyrites, dirt, etc., rise to the surface they are skimmed off by the operator's hand. The clean amalgam which finally remains is then squeezed through canvas. The skimmings obtained are reintroduced into a mortar and treated separately, being ground with the addition of hot water and fresh mercury. When fairly clean, a bit or two of potassium cyanide is added to render the mercury more active by the decomposition of the oxides injurious to it.

Retorting

In retorting, the interior of the iron retort is either chalked or lined with thin paper. The latter method is to be preferred. The balls of dry-squeezed amalgam are put into the retort, broken with an iron rod, and then pressed down until hard and uniform. A good-sized bolt with a nut at the end is a good tool for this purpose. The cover is then put on and luted down with clay.

Cyanide Used

The only chemical used in the mill is potassium cyanide. Of this 26 cans of 10 pounds each were used in a year, during which time 28,793 tons of ore were crushed. The tables are dressed every 12 hours with a weak solution of 2 ounces of cyanide in three gallons of water. The tendency in Gilpin County, as in California, is to diminish the use of nostrums in the gold mills.*

Tables Coated

The tables are brushed twice per day with a mop, mercury being added if the amalgam is found to be too hard, that is, too dry.

Ore Feeding

The ore is delivered by a steam tramway and discharged into ore bins. There are no rock-breakers. The feeding is done by hand. There is one feeder for every 25 stamps, the pay being $3 per shift. The power for driving the machinery is derived from water and steam. There is an overshot water wheel of 50 feet diameter and 4½ feet breast. For four

*The danger of the use of chemicals arises from the very imperfect knowledge which the millman usually has as to the reactions induced. In the above case, for instance, we know potassium cyanide to be a solvent of gold, and it can therefore readily be seen how very careful should be the use made of it.

months the water power suffices, for four months (in the severe winter) the mill is worked entirely by steam-power, and for the remaining four months the two motive powers are combined. Firewood costs $4.75 per cord, delivered. The cost of milling in 1890 was at the rate of 84 cents, but in 1891 it was decreased to 78 cents per ton of ore crushed.

Cost of Milling

The labor employed is thus distributed: The figures are per month of 30 working days, working 75 stamps; one mill-man, $175; one assistant, $100; six feeders (three per shift) at $3 per day, $90 per month, $540; two concentrator men (one per shift) at $3 per day, $180; total, $995, or 38 cents per ton. The day of 24 hours is divided into two shifts.

Labor

In looking down the columns of the comparative table it will be seen that while the mills are all of the same type, and are engaged in crushing ore of a generally similar character, there are yet certain differences which it will be interesting to inquire into. The stamps are all of comparatively light weight, varying from 500 to 600 pounds. This is rendered necessary by this particular style of milling where the high drop would be impracticable with stamps of 850 and 900 pounds, the average of other districts. The speed also is directly affected by the same cause, for the work required to lift the stamps from 16 to 18 inches prevents the rate of drop exceeding 32 per minute for good work. A speed of 40 is probably the practical limit.

Wgt of Stamps

Speed

The slowest drop is that of the New York mill, 26 per minute, and the fastest is that of the Hidden Treasure, 32 per minute. The latter represents the tendencies of the milling practice of to-day, while the former has in this respect adhered to older modes. It is to be noted in addition that the New York mill has the longest drop; in this respect, also, it follows the older practice, for the tendency to-day is certainly not in the direction of an increase of drop. The issue or depth of discharge ranges from a minimum of 11 inches at the Gregory Bobtail to a maximum of 16 at the Prize and Randolph mills. The 16-inch issue represents the older, deeper mortar, while that of the Gregory Bobtail fairly indicates the construction of the more recent plants.

Slow Drop

The crushing capacity of the mills varies from slightly over to a little under one ton per stamp per 24 hours. Such varia-

Crushing Capacity

tion as exists is due to the differences in weight of stamp, height of drop, depth of discharge, speed of drop and fineness of screen. The Prize has the least crushing power per stamp, since it has a comparatively short drop, a deep discharge, and a weight of stamp which is slightly under the average. The deep discharge affects the crushing capacity of the Randolph. The slow drop of the New York is largely made up by the heavier stamps and the increased length of the drop. The different features mentioned are well balanced in the case of the Hidden Treasure, and it has, therefore, a crushing power slightly above the average.

Concentrates

The percentage of concentrates obtained ranges from 12 to 20 per cent., and forcibly indicates the refractory character of the millstuff. The value per ton of these concentrates is very low, averaging $10 to $12 net, and they are only rendered a profitable item by successful and cheap concentration supplemented by light charges at the smelter. Neither the concentrates nor the blanketings undergo further treatment at the mills. They are shipped on railway cars which are conveniently switched at the mill door, and are sent to the various smelting establishments at Denver. The freight is now $1.50 per ton. Ninety-five per cent. of the silver and gold contents, as determined by assay, is paid for and $8 per ton is deducted as smelting charges.* At one time, when this class of material was less plentiful than now, a minimum rate of $7.25 was allowed.

Amalgam Yield

The retort percentage is seen to average from 33 to 40; it depends upon the richness of the ore, since the gold in rich ore is coarser than that of the poor stuff, and hence is less perfectly amalgamated.† It is comparatively high for an ore the character of which is more fairly indicated by the fineness of the gold, which is comparatively low grade, varying from 700 to 850 per thousand.

Water Used

The amount of water used in the mill varies from 1¼ to 2¼ gallons per minute per stamp, and is comparatively low owing to the small capacity of the mills

*The charge varies according to the demand for such material. It has diminished to $4.50 per ton since the above was written.

†In squeezing the amalgam the millman can cause a variation of 10 per cent. in the quantity of gold obtained in retorting, according to the thoroughness with which he squeezes through the canvas the excess of mercury in the amalgam.

and the slight use made of blankets, together with the very high slope of the amalgamating tables, viz, from 1½ to 2½ inches per foot.

Screen wear

In the matter of the wear of the screens and the loss of quicksilver, the divergencies are so considerable as to merit careful examination.

Mercury Loss

The screens used in this district are of local manufacture and are made of planished iron,* size No. 24. The openings are straight, horizontal slots arranged alternately. The screens are graded, according to the size of the openings, from 1, the finest, to 1½, 2, 2½, etc. Numbers 1, 1½, and 2 are those generally in use, and they are conceded to be equal to 60, 50, and 40-wire mesh, respectively. It is to be noted, however, that this type of screen has nothing like the discharge surface of the supposed equivalent in wire mesh. This is seen in practice where, in this district, for instance, a large proportion of the pulp is kept inside the battery until crushed to a size which would allow it to pass a 100-mesh wire screen. While these screens are by no means to be recommended for other districts, they are well adapted to the carrying out of the main idea underlying Gilpin County milling, namely, the retention of the pulp inside the mortar box for a long interval so as to allow of its amalgamation there.

The side which carries the burr edge of the punched openings of the screen is always placed facing the inside of the mortar box, for the evident reason that the burr helps to break the pulp and so prevents the choking of the slots. It is the general custom of the mills to invert the screen after a time, since the passage of the pulp wears the lower portion faster than the upper. The screen is never reversed, that is, the original burr side placed facing outward.

The life of the screen, the time it is used, in the different mills is seen to vary from a minimum of 16 days to a maximum of 81, from two weeks to about three months. This very wide difference is far greater than can be explained by the greater or less attention of the millman and the extent to which he is willing to allow the screen openings to be enlarged by wear. The mills whose names appear in the comparative table are all situated at Black Hawk, and are all erected by the

*An American imitation of Russia iron.

side of the creek which flows down the cañon and under the muddy streets of the dirty old town. Put them in their order of succession, commencing with the Hidden Treasure, which is farthest up the creek, and an explanation of the widely differing wear of the screens is at once suggested.

Mill.	Life of screens—days.
Hidden Treasure	81
Prize	75
Gregory Bobtail	60
New York	25
Randolph	16

The Hidden Treasure receives water which is comparatively clean, and after having used it returns it to the creek, *together with the addition of a certain percentage of sulphuric acid*, as sulphate of iron, derived from the contact of the water with the partially oxidized pyrites in the ore under conditions favorable to a certain amount of solution. The wash of the water in the battery, and the elevation of its temperature due to its rapid agitation under the stamps, are causes operating to aid a chemical action upon the metallic sulphides and sulphates in the ore. The water now reaches the Prize mill, where its slightly increased acidity reduces the life of the screens from 81 days to 75. The Prize in turn contributes its share of sulphates, which again help to injure the screens of the Gregory Bobtail, which mill is a little farther down the creek.

At this point the stream receives the very acid waters which issue from the underground workings of the Gregory mine, and in addition, before it reaches the New York mill, the water washes past banks whose sand is all more or less charged with partially oxidized pyrites, so that when it at length reaches the two lower mills the wear of the screens is measured by days instead of weeks.

The acidulated battery water eats away the edges of the openings of the screens, and thereby rapidly decreases their time of service.

Taking the case of the Hidden Treasure as the most typical, we find 432 tons of the ore are passed through a screen before it is considered worn out. This was the average for 1891. At Grass Valley a screen will live to pass through 200 tons, and at Bendigo (Australia), 134 tons. Among the factors tend-

ing to allow the screen a long life must be noted the very roomy character of the mortar boxes in this district, which diminishes the violence of the splash of the pulp.

Loss of Mercury

Coming to the question of the loss of mercury, we find it to vary from 3.7 to 9.8 dwts. per ton of ore crushed. The two mills which show the greatest consumption of quicksilver have also the deepest issue, and it may be that the further flouring of the mercury added to the ore in the mortar box may be among the causes of increased loss. The increased agitation under the stamp causes more "flouring," that is, the subdivision of the mercury into minute globules, which become coated with a film of foreign matter—the finely pulverized pyrites, for instance—which prevents their coalescing afterward, and so renders them readily borne away by the water to become a part of the value of the tailings-heaps in the creek outside the mill. This is probably so to a certain extent, but the variable loss of mercury at any given mill, and therefore probably between any two given mills, lies mostly in the fact that the more lots of ore that are treated the greater the expense under this head. All these mills are to a greater or less extent custom mills and treat ore coming from a large number of mines. Every lot requires separate crushing; when finished, the plates must be cleaned up each time, the amalgam collected and then retorted, operations all of which mean manipulation and consequent mechanical loss of mercury. The two mills showing the largest figures under this head of mill expenditure are the two which treat, more so than the others, a large number of small lots of ore.

Flouring

Ore

Before venturing upon a criticism of the methods of milling, it will be well to glance at the character of the ore. It has been stated that it is of the refractory class; the percentage of concentrates obtained at the mills and the low grade of the bullion will have confirmed this statement. To give a more detailed description I will not scatter my observations over the districts, but endeavor to describe the ore of the California mine, treated at the Hidden Treasure mill, an ore which is of a representative character and is the product of a representative mine.

The ore as sent down to the mill consists, roughly speaking, of 10 to 20 per cent. metallic sulphides, 15 to 20 per cent.

quartz, 60 to 70 per cent. vein filling other than quartz. The lode matter consists of an altered form of the rocks enclosing the vein; the latter traverses for the most part a dike of andesite which is 17 feet thick. Occasionally the ordinary country rock, a granitoid gneiss, forms one or other of the walls of the lode and contributes to the vein filling. The filling of the vein consists, therefore, largely of feldspathic material. Of the metallic constituents, the sulphides, iron and copper pyrites, predominate. Gray copper (fahlerz or tetrahedrite) and galena are also present in noteworthy proportions. Blende and mispickel (arsenical pyrite) are sometimes seen, and chalybite (carbonate of iron) appears occasionally in the ore from the upper levels.

The gray copper, which here is antimonial, is generally remarkably favorable to the presence of gold. This fact would prove a valuable index in selecting the ore were it not so often confounded with arsenical pyrite. Quartz, especially favorable when of a blue tint, is always associated with the pyrites in rich ore.

The following results of assays made by me* upon a typical piece of ore broken in the 1,700 feet level will throw some light upon the distribution of the gold and silver in the ore.

MINERAL.	GOLD.	SILVER.	REMARKS.
	Oz. per ton.	Oz. per ton.	
Iron pyrites	.65	4.85	White, coarsely crystalline.
Copper pyrites	.85	53.50	Flaky, dark yellow.
Gray copper	.90	38.65	Chiefly covering the last.
Blende	.16	6.45	Black; crystalline.
White quartz	3.32	7.35	Opaque, massive, with small crystals of pyrites throughout.
Bluish quartz	3.56	5.84	
Flinty quartz	.18	1.90	Brown, vitreous.
Feldspathic gangue	.90	2.35	Soft, granular, white.

This analysis bears out the experience of the mills where half the gold contents of the ore are extracted by the first amalgamation in the mortar box. The gold can not, therefore, be chemically combined with the pyrites; on the other hand, the more highly mineralized the ore is the richer also it usually is. There is no doubt that the silver contents are for the most part associated with the copper-bearing minerals, while the gold is enclosed by the quartz, especially that

*In 1886, when in the management of this mine.

quartz which is in immediate association with pyrites. Neither blende nor galena is an attendant upon the gold, and both are a nuisance in the mill.

The following figures further illustrate the character of the ore; they represent the output for 1890: 150.44 tons of smelting ore, averaging $92.79 per ton net; 1,376.03 tons of concentrates, averaging $15.06 per ton net; 10,320.57 tons of millstuff, averaging $7.42 per ton.

The "smelting ore" simply represents the heavily pyritic ore picked out at the mine and shipped direct to Denver. The millstuff yielded 4,766.39 ounces of bullion, worth $16.65 per ounce. Of the total tonnage 98 per cent. was mill ore, and of the total value 84 per cent. Of concentrates the mill ore yielded 13 per cent.

Tests have been made from time to time to determine the completeness of the extraction at the mill. Herewith is given the result of one made by me in March, 1891:

A lot of 8,400 pounds was passed through the breaker and rolls erected at the mine by the company for the particular purpose of accurate sampling. These 8,400 pounds contained four per cent. moisture, leaving 8.064 pounds net.

The assay gave: Gold, 1.85 ounces; silver, 8.75 ounces per ton.

The contents of the 8,064 pounds were therefore 7.96 ounces of gold and 35.28 ounces of silver. At the smelter such ore would be worth* net $26.97 per ton, and have a total value of $108.24.

The ore was sent down to the mill and yielded, after treatment for 18 hours by five stamps, 6.70 ounces of bullion, worth $16 per ounce, or $107.20, and 2,325 pounds of concentrates. The latter contained 15 per cent. of moisture, leaving 1,977 pounds net.† The assay of these concentrates gave 1.76 ounces of gold and 10.34 ounces of silver per ton, or a total for the 1,977 pounds of 1.74 ounces gold and 10.22 ounces silver, worth $45.02, or deducting the freight to Denver (at $1.50 per ton) and smelter charges (at $8 per ton) there remains $35.63.

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* Smelting charges, $12 per ton and a return of 95 per cent. of the gold and silver, according to the New York quotations. Silver is figured at $1 per ounce and gold at $20. Freight, $4.50 per ton.

† The ore therefore contained 24½ per cent. of sulphurets.

Let us compare the results. The milling was at the rate of 84 cents per ton. Therefore the mill return was, after all deductions are made, $139.45. The bullion was $107.20, the concentrates $35.63; total, $142.83, from which deducting the milling cost at 84 cents per ton, $3.38, leaves $139.45. At the smelter the amount received, owing to the larger deductions and charges, reaches the smaller sum of $108.24. Commercially the mill therefore gave the mine-owners better returns than the smelter, although there is no doubt but that the latter extracted a larger percentage of the values in the ore.

As a test of the millwork the figures work out as follows: There were in the ore 7.46 ounces of gold and 35.28 ounces of silver. There were extracted as bullion 5.25 ounces Au, 14 ounces Ag; and in the concentrates 1.74 ounces Au, 10.22 ounces Ag, or a total of 6.99 ounces Au, 24.22 ounces Ag. Thus the mill, including the value in the concentrates, saved 93.8 per cent. of the gold and 71 per cent. of the silver. The mill did not, however, complete the extraction of the gold and silver in the concentrates, so that it actually obtained by amalgamation alone 70.4 per cent. of the gold and 39.7 per cent. of the silver.

This test is very fairly representative of the returns obtained on a larger scale. Generally speaking, it has been found that the mill yields as many ounces of base bullion as there are ounces of pure gold in the ore as found by fire assay. The mill gold is 780 fine, and this proportion very nearly represents the percentage extracted by amalgamation. Considering the fact that the Gilpin County ore is probably the most highly charged with sulphurets of any of the gold-bearing millstuff treated by amalgamation at the chief mining centers of the present day, it is not too much to say that the extraction at the stamp mills is exceedingly good.

That this is so is due to the proper recognition of the necessity for altering modes of treatment in accordance with differences in the character of the ore treated—the first principle of all successful milling. The Georgian and Californian types of stamp batteries were found unsuited so soon as ever the surface quartz had been pierced and the unoxidized pyritic ore was penetrated. The change from the fast-drop, shallow-discharge system to that which has been described

did not take place in a day, but was the outcome of much hard, persevering experimental work. The result is seen in the roomy mortars, slow drop and deep discharge which characterize the Black Hawk mills.

These features are those best adapted to the extraction by amalgamation of the gold in the ores of this particular district.* The ore has been described, and it may be added that in this locality ordinary panning, such as that employed by every prospector, will give no "colors" even with material which in the mill will yield rich returns.† The gold is in a very finely divided condition and very intimately associated with the pyrites. To bring about a separation fine crushing is a necessity, and to cause the combination of the gold so separated with the mercury, time must be allowed for it to sink to the bottom of the mortar box where the mercury chiefly lies.

The slow drop and deep discharge produce a pulverization which is even finer than is indicated by the size of the screen openings, for it is found that about 70 per cent. of the pulp will pass through a 100-mesh wire sieve.‡ Of the pulp a preponderating part is pyrite, which is thus crushed very finely because the deep discharge and roomy character of the mortar allow it to remain inside after it has been pulverized to a size which would allow of its passage through the screen. This fact is of great assistance in causing the fine gold to be separated from the pyrite, with which it is chiefly associated.

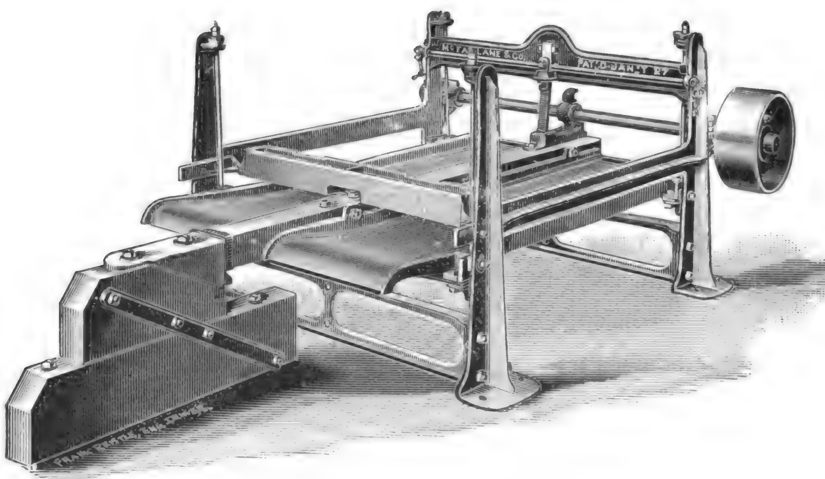
It may appear an error to allow the pulp to remain inside the battery after it has been pulverized sufficiently to allow of its expulsion through the screen. If pulverization were all that is aimed at this would indeed be a mistake, but the battery is here an amalgamating as well as a crushing machine. The delay which occurs before the pulp is expelled enables the gold which has been separated from the pyrite to become amalgamated by contact first with the free mercury introduced by the feeder, and secondly by being splashed against

* See also Chapter I. If stamp milling is to be used this is the best way of using it on these ores; whether another method, such as concentration, would be better, is quite another question.

† Of course, in this statement I exclude the oxidized quartz ore of the surface portions of the veins.

‡ This fact has already been explained as being in part due to the particular variety of screen employed.

the plates at the front and back of the mortar. The roomy character of the mortar is here necessary, for in a mortar whose construction allowed of less space between the dies and the screen, or between the dies and the back of the mortar, the violent splash of the pulp would cause a scouring of the inside plates, which would rapidly remove the coating of amalgam and render the plates useless as gold savers. Thus, to summarize, the deep discharge causes a fine pulverization of the ore, and the long interval between the drops, which with a speed of 30 per minute is noteworthy, allows of the



Gilpin County Bumping Table.

action of gravity among the particles of the pulp. The deep discharge and roomy mortar aid in preventing the production of a too violent splash, and in permitting the pulp to remain inside the battery until the amalgamation required has been effected. Thus all three features—roomy mortar, long drop, and deep discharge—are seen to supplement one another until the proper conditions are obtained.

Black Hawk is the most important gold-milling center in Colorado, and the group of machines whose principle features we have considered is in every way representative of the milling practice. Among the factors tending to increase the cost of handling the ore must be mentioned the universally bad situation of the stamp mills. They are placed in the flat

of the gulch away from the hillside, the consequent want of fall rendering impossible the erection of suitable ore-bins and feeding machinery. This is a fault which may be partially condoned on the ground of their erection having been by no means recent, and is largely due to the desire to utilize as much as possible the motive power in the creek.

The mills are out of date in being unsupplied with rock-breakers. It is true that the advantage derived from the use of a rock-breaker is largely discounted by the fact that the position of the mill buildings would prevent its being supplemented by grizzlies (or sizing bars) and ore bins. At the Hidden Treasure there were a few years ago three small rock-breakers, but owing to the consumption of motive power and the awkwardness* of feeding them they have given way to a return of the more primitive methods of the sledge hammer.

The mills, as we have seen, crush very slowly, and hence there is not that crying need for a rock-breaker which exists in a Californian or Australian mill, but nevertheless there is no doubt that in this respect the Gilpin County batteries are defective, for apart from the improvement in the feeding which follows the introduction of a breaker, the irregular breaking of the ore by the sledge hammer must tend largely to increase the strain upon the mill machinery. This is rendered very evident by noting the wear and tear of the shoes and dies, which in the mills of this section are excessive.

In the matter of feeding it is safe to say that given hand-feeding which is conscientious, it is superior to that of a machine. But man is human, and an occasional pipe or a casual nap are both temptations known to feeders as to other men. On the score of regular and accurate feeding the automatic machine is, therefore, preferable to the average man.

Feeding

Where stamps crush fast the self-feeder is a great economy. How does this side of the question appear in Gilpin County? We find that the low-crushing capacity of the mills enables one man to keep 25 heads supplied. On the score of economy one would therefore, at first sight, acquit the mills of this district; but if the figures are examined a different tale is told.

*Owing to the construction of the mill the ore had to be shoveled *up* into the breakers.

For 75 stamps the cost of feeding comes to a total of $6,500 per year, while on the other hand, if the mill were supplied with the most expensive type of self-feeder, the cost of the additional plant would not be over $4,000. On the score of efficiency I can vouch for the fact that the feeding is regularly and intelligently done, and, with well-tried workmen, leaves but little to be desired. Feeding machines are of but little use unless preceded by grizzlies and rock-breakers; and therefore, notwithstanding a natural aversion to methods which are out of date and machinery which is incomplete, and recognizing the unfortunate position of the mill buildings, a position chosen in the days preceding the introduction of improved labor-saving appliances, I can not say that, either from a share-holder's or millman's point of view, the arrangement of the mills can be advantageously altered. When new mills are built it is to be hoped, now that the mule-wagon as a transporting agency has begun to give way to a steam tramway, that they will be erected in well-chosen sites, giving the fall requisite for the labor-saving machines which have been tried and not found wanting since the days when the Black Hawk batteries were first put up.*

The Black Hawk millman is as interesting and important a feature of the milling as the machine whose working he directs. He has been trained in the best of schools, that of experience, and this factor in making him a good workman has been supplemented by the necessities of a continual watch over the treatment of an ore which is subject to a great variety of mineralogical constitution. Two other points are worthy of notice in this connection. All the mills are to a more or less extent dependent for their full supply of ore upon mines other than those of the owners of the mill itself. The custom milling which characterizes Black Hawk is a power in making both proprietor and millman careful in the treatment of the ore and wide-awake for possible improvements in the methods employed. Further, the milling is recognized to be as important as the mining. This may seem an unnecessary statement, but I have known instances where

*The stamp mills recently designed in Denver or Central City are equipped with rock-breakers, ore-feeders, etc., and leave no room for such criticism as is invited by the old Black Hawk plants.

a good mine well managed has owned a mill whose working has been under the direction of a man who may have been a good miner, a good chemist, anything you will, but who most assuredly was a bad and inexperienced millman. In Australia I have seen a first-class 40-stamp battery consigned to the tender mercies of an engine driver, who, in addition to attending to the machine which gave the power to work the stamps, was supposed to have the general millwork under his charge.

In Gilpin County the work of management is not considered to finish at the shaft mouth; on the contrary, the milling demands the greater attention. The millmen are better paid than the mine foremen. The needs of the district have produced men who are more fully conversant with the bed-rock principles of gold milling than those of almost any other mining center, and such men are not too well paid. Custom milling has had its effect in making proprietors anxious, by placing good men in charge, to gain the confidence of the mining community, and has reacted upon the millmen themselves by encouraging competition in doing good work.

The foregoing description of the methods of this district and the commendation of the skill and intelligence of the millmen must not be construed as an indiscriminate approval of the practice in vogue at Black Hawk. If the stamp mill is to be used, then the way it is used in this locality, for the particular ores of the locality, is correct, but this does not prevent the discussion of the question whether concentration, with or without amalgamation, may not be better than stamp milling. As a matter of fact, the ores of the district are of a noteworthy variety, and in occasional cases the shipment of them direct to the smelter would give better commercial returns; in other instances concentration followed by the stamping and amalgamation of the jig tailings would doubtless prove advantageous, and, indeed, in rare cases straight concentration might suffice.

This opens up a wide subject, and one which can not be considered on the present occasion. The writer simply desires to emphasize the fact that for a large proportion of the output of Gilpin County the existing practice of stamping plus amalgamation plus concentration is the one best adapted to

the peculiar local conditions, and that however incomplete and badly arranged the mechanism of the mills may be, the idea of the amalgamation of the gold in these highly pyritic ores by means of slow-dropping stamps, working in deep roomy mortars, is one warranted by theory and corroborated by experience.

CHAPTER III.

The Typical Stamp Mills of California.

The history of Grass Valley forms one of the most important chapters in the record of gold mining in America. Grass Valley is the mining center of Nevada County, and that county is the leading gold-producing region of California, covering about 20 miles of the length of the main gold belt. To the north it is bounded by the South Yuba and the Bear River, and to the south by the Middle Yuba, names which have become classic in the story of gold discovery.

The pretty town of Grass Valley has a population of 6,500, mostly Cornishmen. It lies among the foothills of the Sierras, and is about 150 miles northeast of San Francisco. The earliest settlement took place in the fall of 1849. The placers which were at that time discovered proved to be of great richness. In June, 1850, the first quartz ledge was found, but its value was not realized at that time. In the following October, however, croppings of extraordinary richness were discovered on Gold Hill, and created a sensation which led to the commencement of vigorous prospecting. Several lodes were then uncovered on Massachusetts Hill, Eureka Mountain, Ophir Hill, and other localities which have since proved very productive.

The first mill built in this district was erected in January, 1851, on the west bank of Wolf Creek, nearly opposite the site of the present Empire mill. This is said to have been the second stamp mill erected in the State of California, priority being conceded to a plant built in Mariposa County in 1850. The latter consisted of eight round stamps driven by water-power. Each stamp occupied a single mortar. Mr. Melville Attwood informed the writer that these stamps revolved, and were the originals upon which the typical Californian stamp was subsequently modeled.

From 1851 to 1866 the Grass Valley district is estimated to have yielded gold of a value to exceed $23,000,000. The sum total to date has been calculated to be no less than $100,000,000. The eleventh census (1890) gave the output for that year as $1,715,248, derived from quartz lodes, and $203,331 obtained from placers, the total being thus nearly $2,000,000. At that time 58 mines were active and 295 stamps were at work. The mint report gives the yield for 1892 as $1,945,406 against a reported production for the preceding year of $2,207,887. It is estimated, however, that the output for 1892 was as much as, if not more than, that of 1891, so that we may put down the production at about $2,250,000. At the present time the mining industry of this old district is in a healthy and vigorous condition. In 1895 the production of Nevada County was $1,789,815.

COMPARATIVE TABLE.

Name of mill.	Number of stamps.	Weight of each stamp.	Number of drops per minute.	Height of drop.	Depth of discharge.	Crushing capacity per stamp.	Crushing capacity of entire mill.
		Lbs.		In.	In.	Tons.	Tons.
North Star	40	850	84	7	4	1.6	64
Empire	40	850	93	7	4¼	1.5	60
Idaho	40	850	95	7	4	2.0	80
W. Y. O. D.	10	750	90	6	5	1.7	17

Description of screen.	Fineness of screen.	Percentage of concentrates.	Value of concentrates per ton.	Retort percentage.	Fineness of bullion.	Consumption of mercury per ton of ore.	Wear of screens.	Consumption of water per stamp per min.
	Mesh.	Per cent.	Dollars.	Per cent.	Per 1,000	Dwts.	Days.	Gals.
North Star—Perf. tin plate	30	3	60	40	851	14½	24	4
Empire—Perf. tin plate	30	2¼	80	40	820	9	15	4
Idaho—Brass wire cloth	40	1	85	42	840	13	11	3¼
W. Y. O. D.—Perf. tin plate	40	2½	100	38	850	11	14	3

The foregoing comparative table gives the figures which best indicate the main characteristics of the milling practice. Of the four plants whose names appear on the list, the North Star is the one which will be taken as a type of the stamp

mills of Grass Valley. The North Star mine was first worked in 1850. In the following year a party of Frenchmen organized a company known by the name of the "Helvetia & Lafayette." In 1857 the mine obtained the name which it now bears. A 16-stamp mill was erected in 1866. The mine has been closed down and reopened at various intervals. Since 1884, however, work has been continuous. The present mill, which was erected in 1886, contains 40 stamps, and its parts are so arranged as to give to a maximum degree an automatic handling of the ore. The mill is often referred to as typical of the best results of Californian experience, and it deserves its high reputation.

A clear idea of the arrangement of the parts of the plant will be best obtained by following the ore in its passage from the entrance at the top of the mill building to its exit as waste at the bottom. The ore arrives from the mine shaft in a car, holding about two-thirds of a ton of ore, and is emptied upon grizzlies or sizing-bars which separate the fine stuff from the large lumps. The former falls through the interspaces, and goes into the lower ore-bins for fine ore, while the latter passes into the upper ore-bins above the rock-breakers. There are eight sets of grizzlies, inclined at an angle of 40 degrees, each set consisting of 15 bars of iron, 12 feet long, ¾ inch wide and separated by spaces of 2½ inches. Recently the spaces have been diminished to 2 inches, thereby increasing the fineness of the ore supplied to the stamps.

The upper ore-bins are three in number and feed three rock-breakers arranged in a row, one beneath each ore-bin. The breakers are all of the Blake pattern, having jaws 15 by 9 inches, and they are fed by means of an ordinary iron shoot. The feeding is regulated by the millman who adjusts the gate opening.

The millstuff as it is reduced by the rock-breaker falls into the lower or fine ore-bins which supply the stamps. The ore is fed to the stamps by means of Hendy Challenge feeders, of which machines there are eight, one to each 5-stamp battery.

Each stamp weighs about 850 pounds. The total weight is thus distributed: Stem, 358; head, 228; tappet, 112; shoe, 152 pounds. The stamps drop from 82 to 85 times per minute through a height of from 6 to 8 inches. Each mortar con-

tains 5 stamps, and each such group (called a battery of five heads) crushes about 8 tons per 24 hours, being at the rate of 1.6 tons per stamp.

Discharge depth

The depth of discharge, the distance from the bottom of the screen to the top of the die, varies from a minimum of 2 inches to a maximum of 6 inches. No serious effort is made to maintain anything like a uniform issue. The crushed ore passes through screens made of tin plate and perforated with holes of such a size and number as make them, it is supposed, equivalent to a 30-mesh wire cloth.

Tables

The pulp is discharged upon amalgamating tables, which are subdivided into three consecutive divisions, termed, respectively, the battery, apron, and sluice-plates. They are all covered with sheets of copper ⅛ inch thick, electroplated with silver at the rate of 1 ounce of silver per square foot of copper.

Concentrators

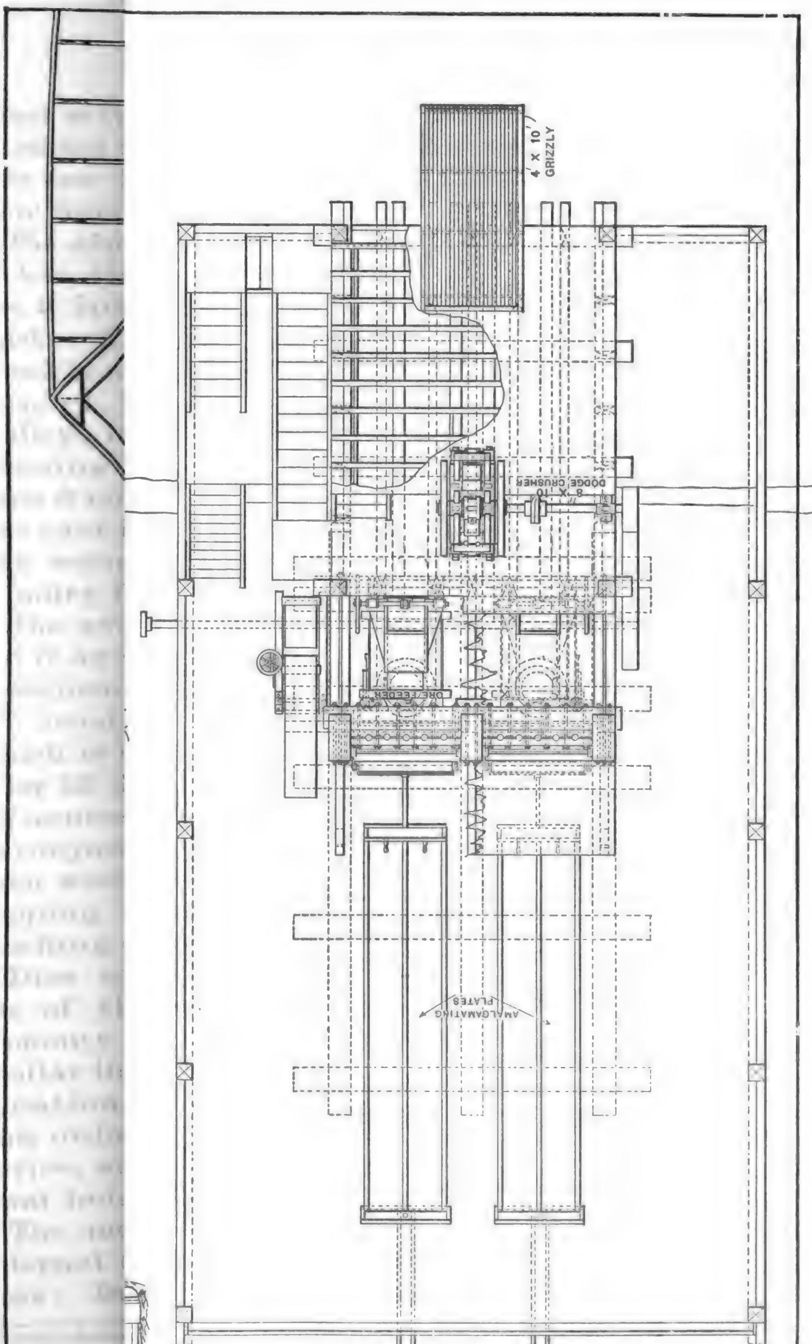
From the amalgamating tables the pulp passes to the concentrators upon the floor below. The discharge from two batteries passes direct to the concentrators, but that from the other six flows first over Rittinger shaking tables, intended to catch any escaping amalgam. The concentration plant consists of 4 Frue vanners and 12 Triumphs, being in the usual proportion of two concentrators to each battery. The concentrators are run at a speed which gives them from 200 to 230 strokes per minute.

The entire machinery of the mill is propelled by water-power. Ninety-three miner's inches (one inch being equal to 1.574 cubic feet, or 11.77 gallons per minute) under a head of 277 feet and a pressure of 212 to 215 pounds per square inch, serve to work a 6-feet Pelton wheel which drives the stamps. Twenty inches of water propelling a 4-feet Pelton run the rock-breakers; and 12 inches, with a 3-feet Pelton, work the concentrators. The transmission of power from the waterwheels is effected by manilla ropes, 1½ inches in diameter.

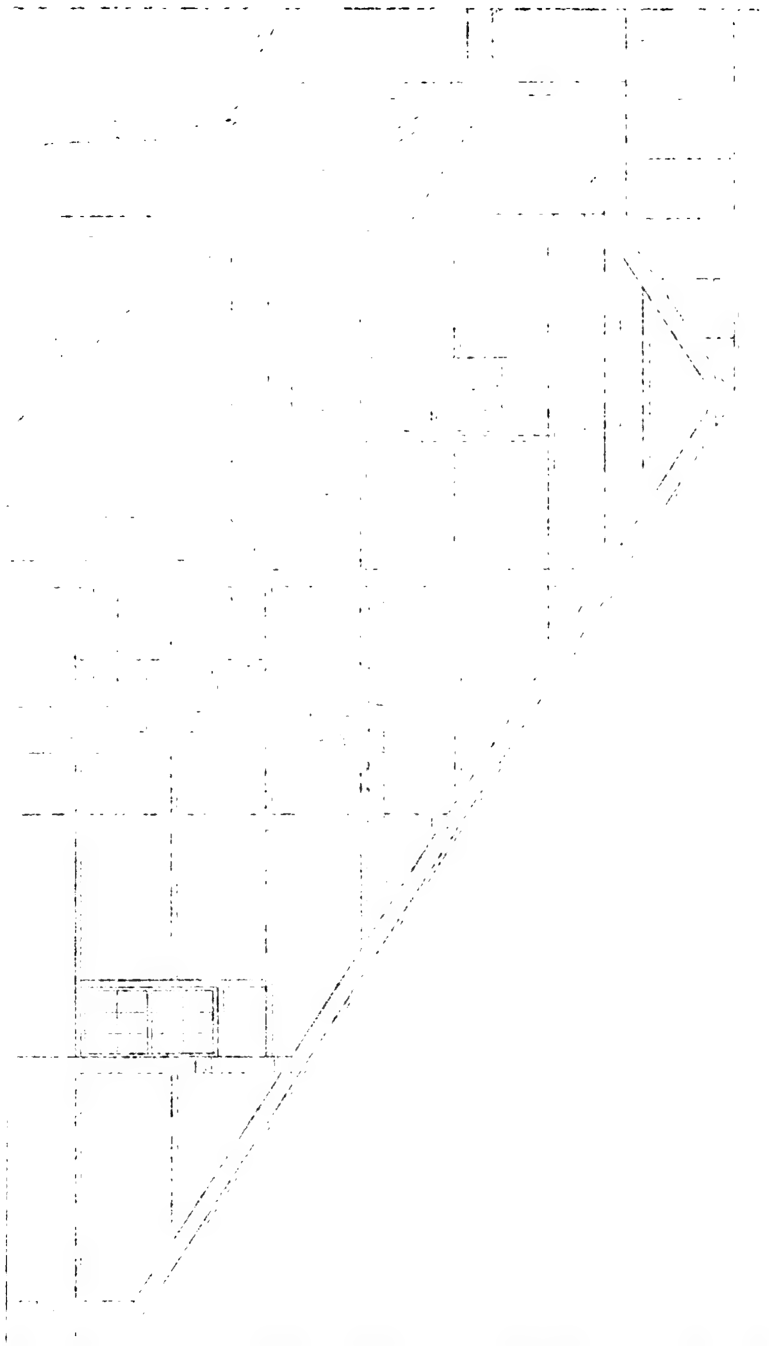
Order of drop

Revolution

Such is the general arrangement of the plant. The following additional details will prove of interest: The stamps in each battery drop in the order of 1, 4, 2, 5, 3. In watching them I found that a stamp often makes a complete turn in three drops; on the other hand, it occasionally falls several



4' x 10' GRIZZLY
DODGE CRUSHER
8" x 10"
ORE FEEDER
AMALGAMATING PLATES



times without making an appreciable turn. On an average it requires five drops to make a complete revolution. The tappets are keyed, not screwed, upon the stem. Screw tappets were used long ago, and discarded. Tappets -

The shoes and dies have the following dimensions: Shoe, 9 inches diameter, 8 inches high, with a tongue 3½ inches thick; die, 9 inches diameter, 5 inches high, with a seat 1¼ inches thick. The former is made of chrome steel, obtained from Brooklyn, N. Y.; the latter is of cast iron from the local foundry. The remnants from wornout shoes are used in Grass Valley, being added to the iron of the dies, so that the latter contains about 20 per cent. chrome steel scrap. The steel costs 6 cents now, but used formerly to cost 9 cents, delivered. The cast iron is delivered at the mill for 4½ cents per pound. The remnants of both shoes and dies are sold to the local foundry for 1½ cents per pound. Shoes and Dies

The average weight of the shoe is 152 pounds; when worn out it averages 48 pounds. It gives a service of 143 days, and therefore wears at the rate of 7.3 ounces of steel per ton of ore crushed. The average weight of the die is 93 pounds, which is decreased to 45 pounds when it is worn out, that is, after 55 days of service.* It wears therefore at the rate of 8.7 ounces of iron per ton of ore. Cast-iron dies, when used in conjunction with steel shoes, are found to produce a more even wearing surface than when steel falls upon steel. The cupping or irregular wear just referred to diminishes the crushing capacity of the stamp.

Dies of 5 and 4 inches depth have both been used. The use of the former as compared with the latter means an economy of the iron, since the portion finally discarded is similar in both cases; but on the other hand, it causes a greater variation in the depth of discharge as the die wears down. This objection can, however, be overcome by employing some device, and there are many that will serve to maintain a constant height of issue.

The mortars are of a pattern common in California. The internal dimensions at the level of the discharge are as follows: Inside length, 4 feet 4¼ inches; inside width, 17½

* For these figures, as indeed for most of the details given, I am indebted to the courtesy of the manager, Mr. Emile R. Abadie.

inches; from the screen to the die is 6 inches; from the side of the mortar to the nearest die ¾ inch; from the back of the mortar to the die 2¾ inches, and between dies ¾ inch. The depth of the mortar below the bottom of the screen is 7 inches. The feedhole comes immediately behind the three middle stamps and gradually widens the upper part of the mortar. The latter is lined with steel plate 1 inch thick.

There is one inside front amalgamating plate. Its use was introduced in 1888. It is of silver-plated copper, and is 52 inches long by 4½ inches wide. It is screwed down to a chuck-block, a wedge of wood which fits tightly against the front of the mortar, and slopes toward the interior at an angle of 45 degrees. See accompanying sketch, Fig. 1, where the distance *A B* is 4½ inches, and *A C* 6 inches.

The screen frame has four partitions which divide the discharge into five parts. Each division is 9 inches wide and 12¾ inches high. Each partition is 1½ inches broad. The frame itself is 4 feet 4 inches long by 18 inches wide. The partitions referred to (see Fig. 2) serve the purpose of strengthening the screen, but they obstruct the discharge and cause a loss (including the ends) of about one square foot of surface.

From the bottom of the screen there is a drop of 6 inches to the battery plate. The latter is 4 feet 2 inches wide, and extends for 18 inches. It is held in an iron frame (*D E*) which is bolted to the mortar. From the battery plate the pulp passes into a trough, then through a distributor consisting of a vertical iron partition pierced by 20 holes, each ¾ inch. There then follows a drop of 3½ inches to the apron-plate. The apron is 4 feet 5 inches wide for a length of 2 feet 6 inches, then it becomes beveled for the remaining length of 2 feet, and decreases to a width of 22 inches before discharging on to the sluices. The apron has a slope of 1½ inches per foot. The sluices are 22 inches wide and 12 feet long, and have a slope of 1 inch per foot. They deliver the pulp to shaking tables (lined with copper) of the Rittinger type. In the case of two batteries, however, these tables have been thrown out, the narrow sluice-plates have also been discarded, and instead the apron has been extended at almost its full width, making a total length of 16 feet, of which the first 2½ feet is 53 inches wide and the remainder 46 inches. The change was made

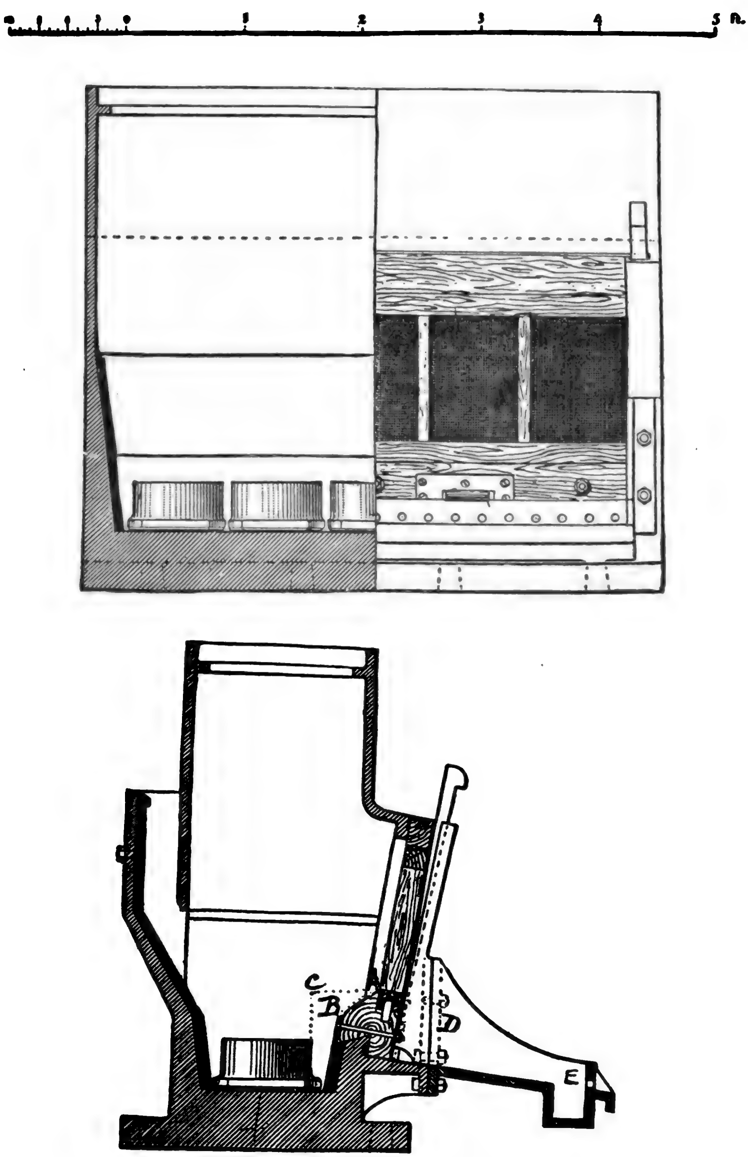


Fig. 1.—Mortar used at the North Star Mill, Grass Valley, Cal.

after my first visit to the mill in 1886, when it appeared to me that the bad arrangement of the amalgamating tables was a very great blemish of an otherwise splendid milling plant. The manager tells me that the alteration is a decided improvement. The accompanying reproductions from photographs* will illustrate the old and the new arrangement as run side by side. The sketch on opposite page, Fig. 3, shows the outlines of the plates, contrasting the old and new style by indicating the former in dotted lines.

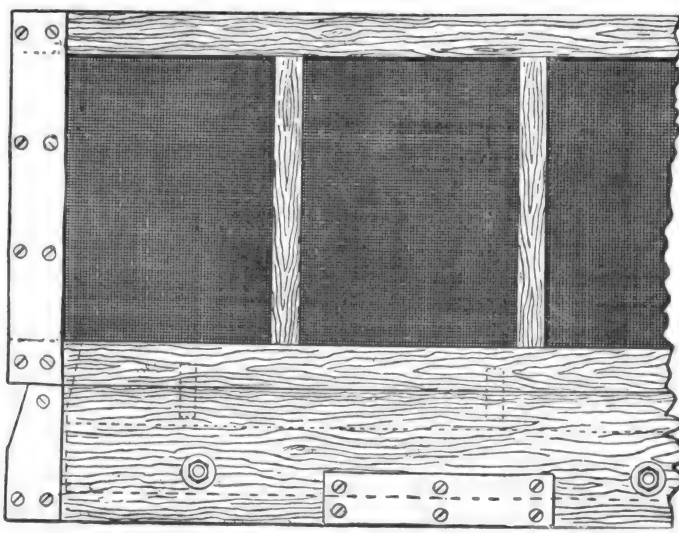


Fig. 2.—Battery Screen Frame.

Needless to say, the change which has been made is a step in the right direction. Even now, however, the diminution in width from 53 to 46 inches appears to me to be a mistake. The width should increase rather than the contrary, for the same amount of pulp and water passes over the lower plates as over the upper; and the gold to be caught by the lower end of the tables is more fine and more readily carried away than that which is caught at the top. I noticed that in the case of the narrow (22-inch) sluices the amalgamating sur-

*Which I owe to the kindness of Professor Christy, of the University of California.

face had been rubbed off (scoured) at the sides, exposing the naked copper; thus proving the increased friction due to the more rapid flow of the pulp, caused by its confinement to so narrow a space. How does the millman expect to catch fine gold under such conditions?

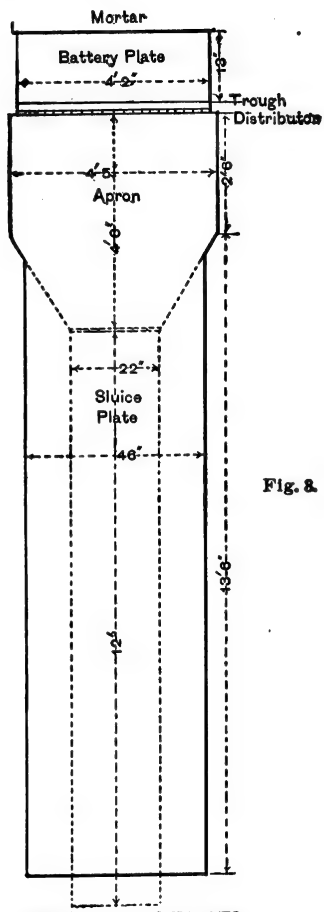


Fig. 8.

AMALGAMATING TABLES
AT THE NORTH STAR MILL
(NO. 3)

The pulp from the amalgamating tables is distributed to the concentrators arranged on the lower floor. It is interesting to note that the experience at this mill is in accord with that of the other plants in this district, namely, that the

Frue vanner requires less attention and gives less trouble than the other endless belt concentrators. It is stated by the manager that at this mill, if all the machines were of the Frue pattern, the mill labor would be decreased by one man per day.

Adding of Mercury

Mercury is added to the ore in the battery at the rate of from one-quarter to one full teaspoonful every hour. Upon weighing several of these teaspoonfuls they were found to average 2 ounces troy. The amount to be added to the ore is judged by the appearance of the amalgamating tables. If the amalgam is very soft and the mercury tends to separate out in globules, then it is clear that the amalgam is more than saturated, and the millman diminishes his dose. If, on the contrary, the amalgam is dry—that is, becomes hard and lumpy—it is evident that more mercury is required.

The proportion of amalgam obtained respectively inside and outside of the mortar varies from time to time, and is dependent upon the richness of the ore, its hardness and grain, the fineness of the screen and the changing depth of discharge. The following figures will illustrate this fact. When there were obtained outside of the battery, on the amalgamating tables, 757, 764, 747, 261, 258, 618, 205, and 200 ounces of amalgam, there were cleaned up from the battery residues and inside plate, the following corresponding amounts: 628, 1,811, 1,030, 459, 456, 1,640, 741, and 732 ounces. The mean ratio is, therefore, two to one in favor of the inside.

The amalgam retorts about 40 per cent. That obtained from the tables has an average value of $6.27 per ounce, equivalent to a gold percentage of 35. That which comes from the inside of the battery is usually worth $8.20 per ounce, equivalent to 47 per cent. gold. Thus, for instance, from 764 ounces of amalgam obtained from the outside plates there were obtained 274 ounces of retorted gold, which on melting gave 269 ounces of clean bullion. Similarly 1,811 ounces amalgam from the inside clean-up gave 795 ounces retorted, or 784 ounces melted, gold. The bullion is worth on an average $17.60 per ounce, equal to a fineness of 0.851. In 1892 ten flasks of mercury were consumed in the treatment of 15,360 tons of ore; this is at the rate of 14½ dwts. per ton.

Clean Up

The general clean-up is bi-monthly. The inside plates are not touched save at that time. The outside plates are scraped

and dressed every morning. The fortnightly clean-up is commenced at 8 A.M., and is completed by 2 P.M. Each battery of five heads is stopped in turn. The dies are taken out, and the residues are fed into the one particular mortar which is the last to be cleaned up. The final accumulation from this battery is removed in buckets, and washed in an ordinary prospector's pan. The iron chips, from the abrasion of the shoes and dies, as well as from that of the drills which are used underground, are removed by a magnet. The headings obtained from the washing of the battery residues are then treated in a small grinding pan—28 inches diameter and 9 inches deep—provided with a false bottom 2 inches thick. The rich residues are subjected to slow grinding, quicksilver being added to collect the gold as it is liberated. The resulting amalgam is removed and washed in warm water. The tailings from the pan are introduced into a barrel whose outside measurements are 2 feet diameter and 3 feet 9 inches length. No more mercury is added, there being already sufficient for the purpose in the pan tailings. Pieces of scrap iron, generally in the form of old nuts, bolts, etc., are added in order to serve as grinders. Cold water is used.

The North Star mill is managed in a very economical and sensible way. Six men compose the total force employed in 24 hours. The following details will be of service:

1 head amalgamator,	by	day	$125.00	per	month,	12-hour shift.
1 assistant	"	" night	100.00	"	"	" "
1 rock-breaker man,	"	day	75.00	"	"	10-hour "
1 mechanic,	"	day	2.25	"	shift	" "
2 concentrator men, day and night			3.00	"	"	" "

The last three on the list are included in the force attending to the concentration. Their united wages average $220 per month.

Water-power costs at the rate of 18 cents per inch. The following figures, given to me by the superintendent, will indicate the distribution of cost:

	1888.	1889.	1890.
Amount of ore crushed	17,269 tons	20,525 tons	14,414 tons
Total costs	$13,326	$16,793	$12,144
Cost per ton	77 cents	81 cents	84 cents
DETAILS OF GENERAL COST:			
Water	$5,230.36	$6,397.75	$4,343.00
Supplies	2,740.43	4,329.47	2,375.31
Labor	5,355.40	6,066.17	5,425.80

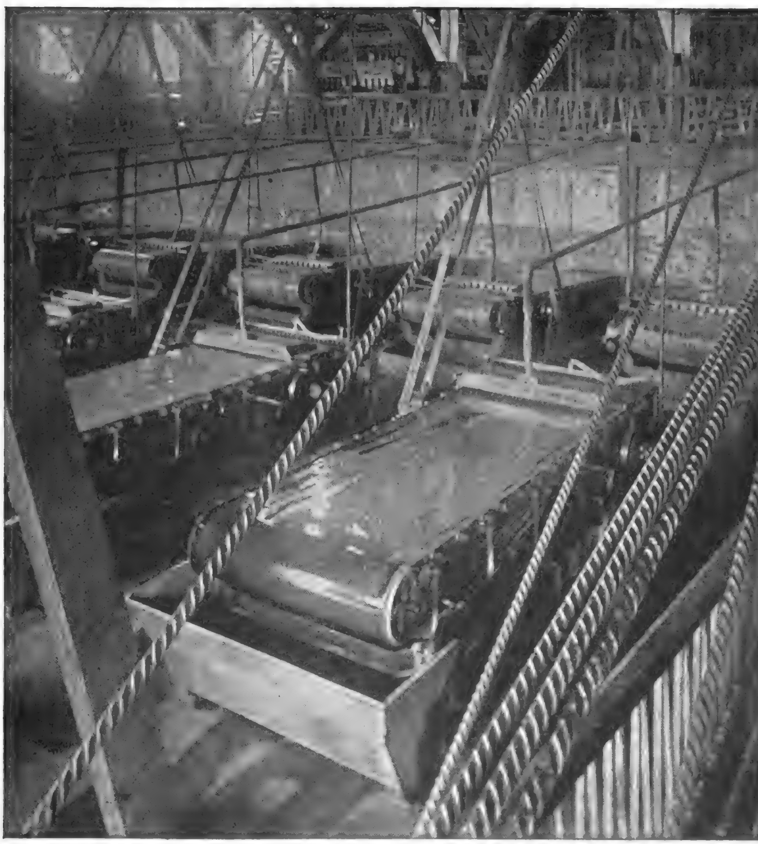
DETAILS OF SUPPLIES:			
Mercury	$ 508.50	$ 699.30	607.25
Shoes and dies	1,183.40	2,562.28	869.61
Other mill castings	260.79	479.97	69.74
Screens	158.00	169.32	173.52
Sundries	629.74	470.10	655.19
DETAILS OF LABOR:			
Concentrators	$2,527.25	$2,560.50	2,377.00
Amalgamators	2,112.00	2,559.17	2,238.80
Rock-breaker	711.15	946.50	810.00
Sundries	5.00	...	...

The mean average figures for this period of three years are as follows: The total cost per ton is 81 cents, made up of the three items: Water, 31 cents; supplies, 18 cents; and labor, 32 cents. For mercury, the cost was 3.38 cents per ton; shoes and dies, 8.84 cents; mill castings, 1.55 cents; screens, 0.95 cents; and sundries, 3.36 cents. In the matter of labor there is the following distribution: Rock-breaking, 4.73 cents; amalgamating, 13.23 cents; and concentrating, 13.53 cents. It is interesting to note that the labor cost in the concentration department exceeds that of amalgamation. While these figures do not by any means come up to some which are often quoted to show how cheaply gold ores can, under favorable circumstances, be worked, yet having due regard to the conditions obtaining at the North Star mine they are undoubtedly excellent. The ore and its encasing rock are of more than usual hardness, and this fact prevents that rapid crushing and minimum wear and tear which help so much to reduce the cost of treatment at other mills.

The Empire mill is the older plant, having been erected in 1883. It treats the ore of a mine which has been a very steady and large producer. There are 40 stamps arranged in eight batteries of five heads. Each stamp weighs 850 pounds and drops 90 to 95 times per minute through a height of 7 inches. Each battery crushes 7½ tons per day, being at the rate of 1½ tons per stamp. The ore is very hard. Two rock-breakers and 8 Challenge ore-feeders are employed. A 5-foot Pelton wheel supplies the motive power. It is under such control that the entire mill can be stopped in 15 to 20 seconds.

The depth of discharge varies from 3½ to 5 inches. The tendency of late has been to diminish it because the mine has been unable to produce ore of such a high grade as formerly, and economical reasons made fast crushing necessary. The

discharge has been gradually reduced from 6 inches to an average of 4¼ inches. As the dies wear down old dies are placed underneath, so as to maintain the height of the issue within certain limits.



North Star Mill, Grass Valley, Cal.

Formerly iron plates were used as false bottoms, but they were found to break too often. In order to further regulate the discharge, wooden cleats are fixed to the bottom of the front of the screen. As the dies wear down they are removed. The chuck-block or wooden wedge to which the single amalgamating plate is attached has a straight face. Originally it

was convex, but this was found to bring the plate too near to the stamp and to injure its surface. The plate is 4 feet 2 inches long by 4 inches wide. It is of plain copper.

Of the total amalgam obtained in the mill an average of 75 per cent. comes from the inside of the mortar. The variation is between 50 and 85 per cent. The tendency of late years has been to increase the proportion saved inside the battery by using finer screens.

North Star Mill, Grass Valley, Cal.

Screens

Until lately brass wire-cloth screens, 30 and 40 mesh, were used, but they have been replaced by perforated tin plate of an equivalent fineness. The surface of the tin plate is smoked on the blacksmith's forge, the idea being that this will prevent the adhesion of amalgam. The tin wears off in about a week. The brass wire is said to cost at the rate of

$1.55 per screen and to give a service of 25 working days, while the tin-plate screens cost 55 cents each and last for 15 days.

From the mortar the pulp passes out upon the amalgamating tables. The battery plate is 4 feet 2 inches wide and 2 feet long. It has a slope of 2¾ inches per foot. The apron, which follows, has a width equal to that of the battery plate, but it narrows to 4 feet and then is beveled so as to diminish to 2 feet. The gradient is 1⅞ inches per foot. The sluices are 2 feet wide and 12 feet long. They slope at the rate of 1 inch per foot. All these amalgamating tables are covered with silver-plated copper having 2½ ounces of silver per square foot of copper. Tables

The pulp then goes to the concentrators — 16 Triumph machines. It is said that they give more trouble than the Frues, but it must be added that at this mill the introduction of the Triumph concentrator was due to the result of a test extending over 60 days made between the Frue and the Triumph. As is often the case, however, in these matters, the trial was not altogether conclusive, because it is claimed that the result was largely due to the superior skill of the man who had charge of the working of the Triumph. Concentrators

The concentrates have a gross value of from $75 to $300 per ton. The average is from $75 to $100. The yield of sulphurets is at the rate of 2 to 2½ per cent. The clean-up is made bimonthly. It is begun at 6.30 A.M., and the amalgam has been retorted and the gold melted by 4.30 P.M. Any replacing of new for old shoes and dies, if required, is done at this time. This mill employs chrome steel for both shoes and dies. When the supply of steel runs short, cast iron from the local foundry is used in its place. The service of the chrome steel is very good, giving a regular and even wearing surface. There is no marked difference to be noted in this respect between the chrome steel and the local castings, the former being more expensive, but wearing longer than the latter. The millmen prefer the steel because its longer time of service necessitates less frequent changes to be made, and therefore gives them less labor. Clean Up Shoes and Dies

The mill, including the concentrators, uses from 12 to 15 miner's inches of water. This is equal to 4 gallons per stamp Water

per minute. Each Triumph takes 1½ gallons per minute of water, in addition to the battery water accompanying the pulp. From 40 to 50 pounds of mercury are consumed in crushing from 1,400 to 1,500 tons of ore. This is equivalent to 9 dwts. troy per ton of ore treated.

Sampler

Extraction

In leaving the mill the tailings are passed through an automatic sampler which takes six samples per hour. It is the invention of Mr. Starr, the former superintendent, and appears to be an excellent device. The results indicate that the mill saves from 85 to 87 per cent. of the gold in the ore. The tailings rarely contain less than $1 per ton.

Stamps wgt. Speed drop discharge

The W. Y. O. D. (Work Your Own Diggings) is a new mill, having been erected in 1890. It contains 10 stamps weighing 750 pounds each. The speed is regulated at from 90 to 100 drops per minute. The drop varies from 5 to 7 inches. The depth of discharge has a minimum of 4 inches and a maximum of 6 inches. The dies, which are made of cast iron, are used for six weeks and then discarded. This prevents a wide difference in the issue. Chrome steel shoes are used and give excellent service.

The mill is provided with 1 rock-breaker (Gates) and 2 automatic feeders (Hendy Challenge). The crushing capacity is at the rate of 510 tons per month of 30 days. This is the only mill in Grass Valley which works on Sundays.

Amalgam

About one-half of the amalgam obtained from the inside of the mortar is taken from the one amalgamating plate, which is 4 feet long and 4 inches wide. Of the total saving of the mill by amalgamation two-thirds comes from the mortar. The tendency is to endeavor to increase the importance of this inside amalgamation. The amalgamating table consists of one surface 50 inches wide and 14 feet long. It has a slope of 1⅛ inches per foot and is plated with 5 ounces of silver per square foot of copper.

Table

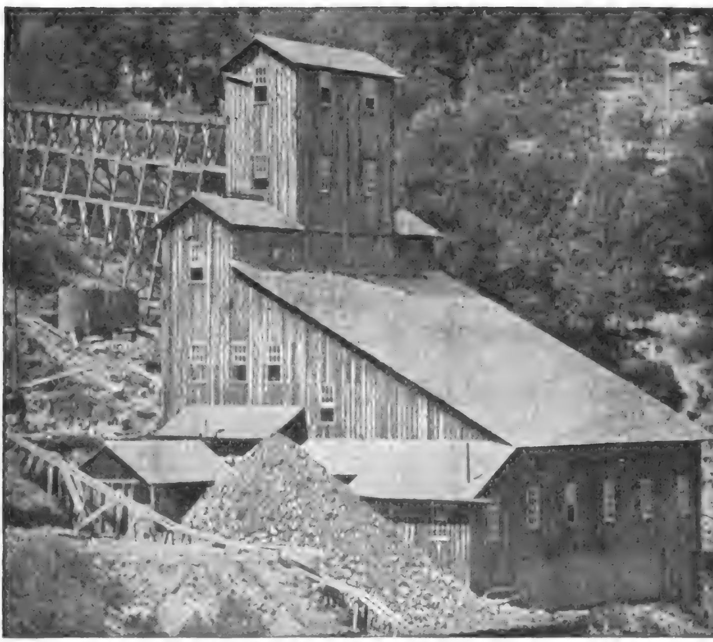
Screens

Brass wire-cloth screens of 40 mesh have been replaced by perforated tin plate. The latter give a service of 14 working days. They are considered to wear more uniformly than the wire cloth, the brass of which becomes amalgamated at the edges, and so weakened.

Concentrators

The pulp from the table goes to 4 Frue vanners, which extract 2½ per cent. of concentrates worth from $60 to $275 per

ton, the average being about $100 gross. They are sold to the local chlorination works, which charge $16 per ton for treatment and hauling. About 90 per cent. of the gold value is returned, the silver being negligible.



The Union Mill, San Andreas, Cal.

Three flasks (each 76½ pounds avoirdupois) of mercury are consumed in crushing 6000 tons of ore. This is equivalent to 11 dwts. per ton. The water used in the mill amounts to 2½ miner's inches, being at the rate of 3 gallons per stamp per minute.

Mercury Consumed. Water do

The mill is run by steam-power. The plant is small, but very sensibly designed. The tailings are said to contain an average of $1.10, being equivalent to a saving of from 87 to 90 per cent.

Power

Saving

The Idaho mill is a very old plant, belonging to a famous old mine, and has undergone frequent alterations. The figures given in the comparative table indicate that it works on lines similar to the Empire mill.

Before concluding this description of the mills of Grass Valley, it will be well to draw attention to one or two matters of detail.

+ *Depth of Discharge.*—At the North Star there is no serious effort made to maintain a uniformity in the depth of discharge. This is a mistake. A certain depth of discharge will give the conditions most favorable to good work with a certain kind of ore; it should be the business of the millman to ascertain what this particular depth is, and it should then be his effort to prevent too wide a variation from it. At the Empire this is done in the two ways previously described, while at the W. Y. O. D. mill the dies are only used for six weeks and are then discarded.

The plan adopted in the latter case is a sensible one because, though there is a waste of iron in discarding dies that are not quite worn out, this loss is lessened by the sale of the scrap, and is offset by the prevention of that excessive depth of discharge which occurs when dies are allowed to wear down to the bitter end, and consequently seriously diminish the crushing capacity of the battery.

+ *Screens.*—In the matter of screens the millmen of Grass Valley have taken a retrograde step. The adoption of round-punched tin-plate screens in place of wire cloth does not appear to the writer to be any sort of an improvement. Many years ago the ordinary round-punched Russia iron gave place to angle-slot screens for the reason that it was found that the round-punched iron was constantly becoming clogged. The openings of the angle-slot screen kept themselves more clear.

In time it was found, however, that the angle-slot screen was unsatisfactory, because the sizing which it did was, to a marked degree, irregular. Brass wire cloth was introduced. The time of service of the angle-slot was nearly twice as long as that of the wire cloth, but this was offset by their cost, which was also twice as much. The former cost $3.90 per screen and the latter $1.94. The brass wire was made of 29–30 and 30–31 wire. Steel wire cloth was also tried, but while it wore well—that is to say, it was not quickly abraded—yet its usefulness was much diminished by the fact that the horizontal wires shifted, presenting the appearance shown in the accompanying sketch, Fig. 4, where it is evident that at *bb*

there will be scarcely any discharge, while at *a* a coarse pulp can readily find an exit. Therefore they were discarded and brass wire cloth, which did not share this defect, was substituted.

The average life of a brass wire screen, 30 mesh, was found to be from 20 to 24 days, that is to say, it served to discharge about 200 tons of crushed ore. During a period of 4 years there were crushed at the North Star mill 70,000 tons of ore, and the expense in screens during this period amounted to $675. The screens were made to order in rolls 100 feet long and of such a width, 45 inches, as permitted of three strips being cut. Each strip was 15 by 52 inches. One roll of brass wire cloth cost $135, so that the screen cost $1.94. The expenditure under this head was therefore slightly less than 1 cent per ton of ore treated.

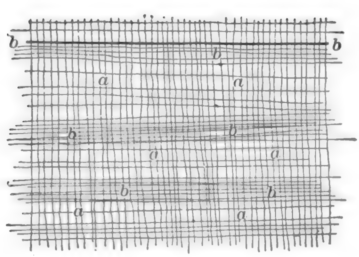


Fig. 4.

Recently, punched tin-plate screens have been introduced; and as is so frequently the case in matters of this kind their adoption by one plant has led to their use at nearly all the Grass Valley mills. It is often the practice here, as it used to be at Angels Camp, Calaveras, to burn off the tin upon the blacksmith's forge, with the idea that in this way the iron plate became annealed and therefore toughened. Since the tin will amalgamate, its removal also prevents the adhesion of mercury. When the tin is not removed as above described, it is found that at the end of the first week's service the abrasion of the pulp has rubbed off the tinned surface. In this respect tin plate is no improvement on brass wire. It is true that the brass becomes partially amalgamated and the screen rots in consequence; but previous to the time when

this action has become of any importance, sharp bits of quartz have cut the wire, and it has become necessary to make a patch and to turn the screen frame upside down. Mr. Abadie informed me that he found that the brass wire had a shorter life when the stamps were crushing waste—that is, wall rock containing only a very small amount of gold—and very little amalgam was being discharged through the screens, than when good gold quartz was being treated and more mercury was being added to the millstuff.

Brass wire screens now cost $1.55 each, which is about three times as much as the tin plate, which costs only 55 cents per screen; the former gives a service of 25 days, as against 14 to 15 days for the latter. But the relative expense is not worth notice since per ton of ore it is less than 1 cent. As compared to angle-slot or round-punched screens the wire cloth has the immense advantage that, with openings permitting of the passage of particles of equal size, it has a much larger area of discharge per square foot of screen. It therefore gives a more even product and produces less slime. A screen is a device for sizing the particles of pulp to be delivered to the amalgamating or concentrating apparatus placed below the stamps. Wire cloth most nearly gives the sizing medium required, while angle-slot or round-punched iron plate only very imperfectly fulfills this function.

All the Grass Valley mills have their screen frames at a forward inclination of about 10 degrees. As compared to a vertical arrangement, this helps to spread the pulp over the surface and to give the aid of gravity to the force of the splash in ejecting the crushed ore.

+ *Amalgamating Plates.*—It will have been noted that the tendency at Grass Valley is to increase the amount of silver put into the electroplated copper amalgamating plates. At the North Star the plates carry 1 ounce of silver per square foot of copper; at the Empire, 2½ ounces; and at the W. Y. O. D., the newest mill, the quantity has been increased to 5 ounces per square foot.

The milling practice of this typical Californian mining district has undergone one important modification during recent years. I refer to the introduction of an inside amalgamating plate. This was done at the North Star mill in 1888. It was

found that the shallow discharge brought the plate too near the stamp; therefore the chuck-block was inserted. The latter gives a sort of false lip to the mortar box and serves to heighten the discharge. It is a wooden block, extending the whole of the front of the inside of the battery, and to it the plate is attached. (See drawing, Fig. 1, of mortar at North Star mill.) At the North Star and W. Y. O. D. mills twice as much amalgam is saved inside the mortar as upon the tables outside, while at the Empire from 50 to 85 per cent. of the total amalgam obtained by the mill comes from the inside of the mortar. Of the saving thus effected in the battery, about one-half comes from the plate itself and the other half is derived from the treatment, at the fortnightly clean-up, of the battery residues.* The tendency at Grass Valley is to increase the percentage of saving effected within the mortar.

This feature of the milling practice is of great interest, since it indicates a tendency to make the mortar more of an amalgamating machine than has heretofore been the case in California. On the Pacific slope the stamp battery is primarily a crushing machine, hence the quick, short drop and the shallow discharge. The work of amalgamation has hitherto been left for the most part to other apparatus, and the introduction of an inside amalgamating plate tends to bridge over the wide divergence existing between the milling methods of Colorado and California. The modification is right in principle to the extent that the sooner you catch your gold the less likelihood there is of loss, and if you can extract it in the mortar, do not allow it to pass out in order to arrest it on the tables. On the other hand, the cheap milling of California is largely dependent upon the rapid crushing of the ore by the fast-dropping stamps; and the use of an inside plate, by demanding an increase in the depth of discharge, compels a diminution in the crushing capacity of the mill. It becomes a business proposition to be carefully weighed by the manager of the mill, who has to decide whether the increased extraction in the mortar more than compensates for the less rapid reduction of the ore. The best practice is that which pays best.

* In the Gilpin County mills all the amalgam saved inside is obtained from the two front and back inside plates.

The little W. Y. O. D. mill sets a good example to its larger and more pretentious brethren in the matter of the arrangement of its amalgamating tables. These are 50 inches wide and 14 feet long, giving a clear, wide, full amalgamating surface, which shows much good sense and judgment compared to the short aprons and narrow sluices of the other plants. The narrow sluice-plate of the Californian mill is a relic of the days when gravel-mining apparatus was introduced into quartz-crushing mills; it is indefensible, and the sooner it is discarded the quicker will there be removed the only serious blemish of the typical American mill.

The accompanying drawing will illustrate a representative Californian plant.

Grass Valley has been a school to many good millmen, and it has been the birthplace of many of the most important improvements introduced into gold-milling practice. At another time the writer hopes to trace the gradual growth of the American stamp mill from the rough and clumsy machine of the early fifties to the magnificent and complete mechanism whose muffled thunder now echoes among the foothills of the Sierra Nevada.

CHAPTER IV.

Californian Practice in Amador County.

Amador County lies extended among the rolling foothills of the Sierra Nevada, sloping from the pine-clad mountains down into the dusty valley of the San Joaquin. The county has its greatest extent east and west, but from the Cosumnes River on the north to the historic Mokelumne on the south it covers 17 miles of the main gold belt of California. It is a mining district whose record fills some of the first and most interesting pages of the history of Californian gold discovery. As early as 1848 mining was begun in Hicks Gulch, a tributary of Sutter Creek. The story of that early mining is all of gulches and of creeks, for the diggers followed the running stream and had not yet realized the importance of the quartz lodes. In 1851 a stamp mill was erected on Amador Creek. This date also marks the commencement of exploration on that great auriferous belt which extends through several counties, and has become known as the "mother lode." In 1856 there were 20 stamps working ore from the Keystone mine, 38 on the Spring Hill, and 20 at the Amador mine. Motive power was obtained from the creek by using large overshot wheels. The gravel deposits of the mountain streams became exhausted about the year 1860, and quartz mining received a fresh impetus. In 1866 there were 296 stamps crushing the produce of 15 mines. In 1874 the number had increased to 335 stamps, supplied by 13 mines. It is evident from these figures that while the milling capacity had grown, the number of mines which afforded the ore supply had not increased. The explanation is to be found in the construction of the Amador canal, which by conveying water-power to the district enabled a very considerable enlargement of the mills

to be carried out, and made this district one of the most busy and prosperous of the gold-mining regions of California. In 1879 the Amador Canal Company owned 45 miles of main ditch. The total length of canals and ditches was no less than 94 miles. The water is delivered to the mines under a head varying from 130 feet to 470 feet.

In 1878 there were 510 stamps at work in Amador County, crushing the ore of 22 mines. In 1890 the number of stamps was almost exactly the same, 511, distributed in 18 mills, treating the ore of 18 mines.

COMPARATIVE TABLE.

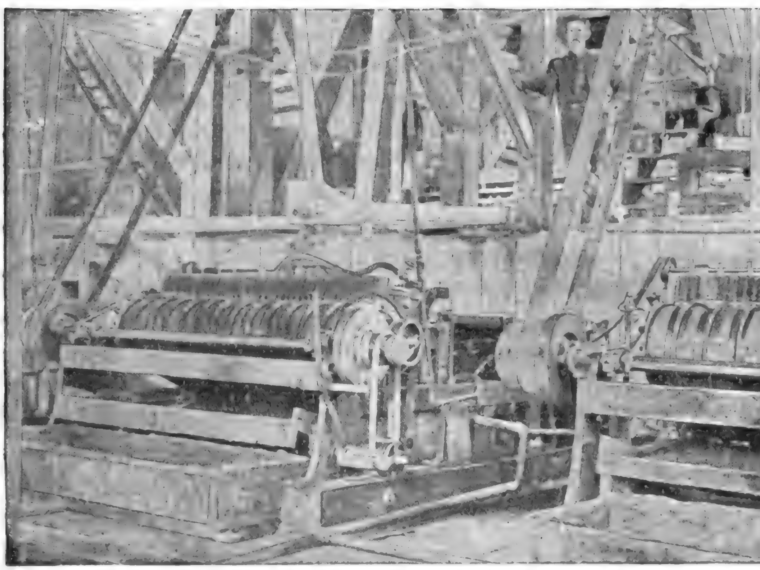
Name of Mill.	No. of stamps.	Weight of each.	Drops per min.	Height of drop.	Depth of discharge.	Capacity per stamp.	Capacity of mill.
		Lbs.		In.	In.	Tons.	Tons.
Gover	20	800	96	6¾	8	2.2	45
South Spring Hill	40	750	93	7¼	7½	2.3	92
Wildman	30	750	92	7	7¼	2.3	65
Keystone	40	750	90	6	7	2.5	100
Kennedy	40	850	83	6½	7	2.5	100
Clinton	20	1000	85	6	7½	3	60

Kind of screen.	Wear of screen.	Percentage of concentrates.	Value of concentrates.	Retort percentage.	Fineness of bullion.	Loss of mercury per ton of ore.	Water per stamp per minute.
	Days.		Dollars.		Per 1000.	Dwts.	Gals.
Gover—Several varieties	45	1	110	37	825	2.6	3¼
South Spring Hill—No. 8 angle-slot	34	1½	40	45	830	*	3½
Wildman—No. 6 angle-slot	36	1½	60	42	809	4.5	3
Keystone—No. 8 straight slot	32	1½	110	45	830	6.5	3¼
Kennedy—30-mesh brass wire	30	2	125	42	828	*	3
Clinton—20-mesh brass wire	25	2	100	30	820	*	5

During 1892 the State of California produced gold having a value of $12,571,900. Of this total Amador County yielded very nearly $1,500,000. At the present time the district is fairly prosperous; some of the old mines have recently been reopened, and there is reason to expect that there will be a renewal of that activity which characterized the county a few years ago. In 1895 the production was $1,391,929.

*Figures not obtainable.

The foregoing table gives the chief figures indicative of the methods of milling at five of the best-known mills. They are scattered among the series of picturesque little mining towns which reach from Drytown to Mokelumne Hill. Most of the plants are old, but have been variously modified so as to meet the changing requirements of the ores.



Interior of the Gover Mill, Amador County, Cal.

Of the five mills whose names appear on this list I shall endeavor to give a detailed description of one, and that one will be the Gover mill, which in many ways fairly typifies the best practice of Amador County. This plant is located about two miles north of the town of Amador. The mill, the mine, the tramway, which connects them and the surrounding hill-slopes with their clumps of white oaks, compose a picture thoroughly characteristic of the mining regions of the Californian foothills. The accompanying photograph will therefore prove of interest.* The Gover mill is 19 years old; it is a comparatively small plant and consists of only 20 stamps. The weight of each stamp is now about 800 pounds, though

*For the two very excellent photographs illustrating this contribution I am indebted to Prof. S. B. Christy.

when new the figure was 850. The speed is regulated at 96 drops per minute. The height of the drop is changed with the hardness of the ore to be crushed, the minimum being 6 inches and the maximum 7½ inches. The capacity of the mill shows a wide variation, according as the ore is hard or soft, free from sulphide minerals or rich in them, carrying the gold in a coarsely divided condition or containing it intimately mixed with pyrite. The minimum capacity is 40 tons and the maximum 85 tons per day. The average is about 55 tons or 2¾ tons per stamp per 24 hours. At the present time the ore is of high grade and an endeavor is made to retain the gold inside the battery; the crushing capacity is therefore somewhat sacrificed, and averages 45 tons per day. On the other hand, last year when the ore was low grade and valuable more for the gold-bearing pyrites than for its free, readily amalgamable gold, the mill was used more as a crushing machine, preparing the millstuff for concentration, and at that time 2,600 tons per month were ordinarily treated, being at the rate of over 80 tons per day or about 4 tons per stamp.

Screens

Several kinds of screens are used, in accordance with the character of the ore being crushed. Brass wire cloth, 30 mesh, is employed for ore of medium hardness, carrying gold of medium fineness. Such a screen lasts for from 35 to 55 days. For ores rich in pyrites, steel wire cloth, 20 mesh, is generally used. It gives a rapid discharge and wears from 20 to 30 days. When the ore contains the gold in a fine state of subdivision and, as usually happens, is also very hard, then punched Russia iron, size No. 7, is employed. This tends to keep the pulp inside the mortar and to give fine crushing. Such screens last from 40 to 60 days.

In every instance the wear of the screen is most irregular. This is due in large part to the chips of wood (from underground timbers) which get stuck in the screen openings and make frequent scraping necessary. Incidentally I may mention that by actual count I found that the No. 7 Russia iron screen contained 10, the 30-mesh brass wire 23, and the 20-mesh steel wire 18, holes per linear inch. The brass wire gave much the most free discharge and the most even crush-

ing, the steel the coarest crushing and the most rapid discharge, and the punched iron the most uneven crushing and the most irregular discharge.

From the battery the pulp passes over a series of amalgamating tables, to be shortly described, and then to the concentrators. These last are 4 Woodbury machines, constructed on the principle of an endless rubber belt having 13 subdivisions. The partition into narrow strips is supposed to give a greater capacity than the plain belt. It does less clean work, however. Ordinarily at this mill the yield of concentrates is equivalent to 1 per cent. of the ore crushed. In 1891 650 tons of sulphurets were obtained during the crushing of 22,400 tons, being in the proportion of about 2¾ per cent. At that time the assay value of the concentrates was about $100 per ton; now it ranges betwen $100 and $125 per ton. They are sold to the chlorination works at Amador City and at Drytown.

Tables

Concentrates

The water used for milling purposes, inclusive of the concentrators, amounts to 10 miner's inches, or 108 gallons per minute, when treating ore heavy in pyrites, and diminishes to 6 miner's inches, equivalent to 65 gallons per minute, when ordinary quartz is being crushed. Immediately outside the mortar there is a pipe for distributing clear water. As a rule more water is wanted on the plates outside than is required inside the battery. When the reverse is the case the clear water is diverted inside so as to make up the requisite quantity.

Water used

The consumption of mercury depends upon the richness of the ore. While the gold of rich ore is also usually coarse and requires proportionately less mercury than the gold which is in a fine state of subdivision, and which therefore becomes more thoroughly amalgamated, yet in practice it is found that the consumption of mercury per ton of ore is greatest with the richest ores because they require the more free addition of mercury, and therefore the greatest opportunity of loss by subdivision of the mercury when in the battery. The presence of pyrite is also an important factor. The friable, finely divided particles of pyrite coat the globules of mercury and prevent them from coalescing. In the treatment of 22,400 tons of ore in one year, 200 pounds of mercury were con-

Mercury used

sumed, being at the rate of 2.6 dwts. troy per ton. During the week of my last visit the ore being crushed was of high grade, and 60 ounces of mercury were being used per 24 hours. It is added to the ore in the battery by the amalgamator at regular intervals in a small wooden spoon, and most of it is,

Amalgam

of course, recovered when retorting the amalgam. Thus, in retorting 350 ounces of amalgam there were recovered 191 ounces of quicksilver. The amalgam is now worth $7.50 per ounce, but usually averages $6.55 per ounce, equivalent to a retort yield of 37 per cent. gold.

Saving

The gold saving is done directly in the mortar itself, and on the amalgamating tables outside; also indirectly by the concentrators and a system of blankets which follow. As already stated, free mercury is added to the ore as it is fed into the battery. This serves to collect some of the gold which then settles as amalgam to the bottom of the mortar, being deposited in the corners and between the dies. The

Plates

work of gold saving is, however, supplemented by the use of an inside copper plate. This is placed at the front of the mortar, immediately under the screen frame. It is fixed to a wooden block called the "chuck-block," whose inside surface is curved and carries the copper plate, while the front fits tightly against the lip of the mortar. The plate is 6 inches wide and the full length of the interior. The depth of the

Chuck Block

chuck-block is 8 inches, and it serves to heighten the issue by raising the front of the mortar. It has been found that a curved chuck-block (see Fig. A) gives a more rapid discharge than a straight one (see Fig. B), such as was in use formerly at the Plymouth Mill.

Clean Up

Mill

Of a total clean-up of 350 ounces of amalgam, 277 ounces, or 79 per cent., were obtained from inside the battery, and 73 ounces, or 21 per cent., were scraped from off the outside amalgamating tables. Of the total obtained inside the battery, 221 ounces, or 63 per cent. of the whole 350 ounces, came off the plate, and the balance of 56 ounces was obtained from the treatment of the sands remaining inside.

Tables

The pulp as it issues from the mortar is discharged upon a series of amalgamating tables having various dimensions. The screen surface is small; it is only a strip 4 inches wide by 4 feet long. This is one reason for the comparatively long

service given by the screen, and as the discharge of a mortar is nearly always confined to the bottom part of the screen surface, it is an arrangement which does not, I think, seriously interfere with the rapidity of the issue.

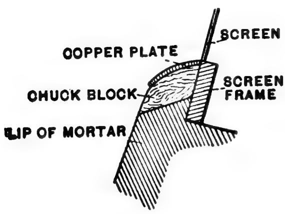


Fig. A

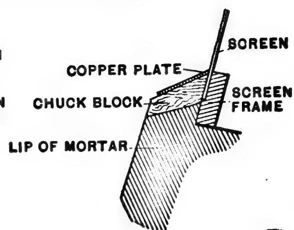
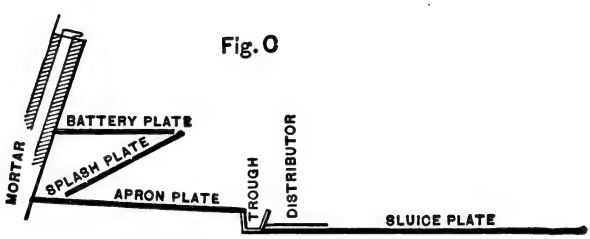


Fig. B

Fig. C



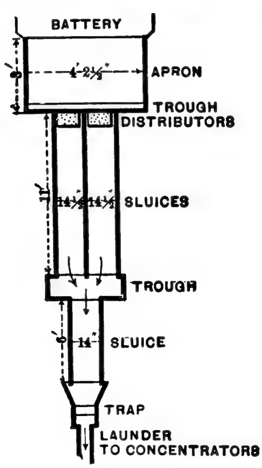


Fig. D.

The accompanying sketches illustrate the arrangement of the amalgamating tables. The photograph of the interior of the mill will also help to make the description clear. On issuing from the mortar the pulp falls upon an amalgamated plate,

called the battery plate. This is 4 feet $2\frac{1}{2}$ inches wide and 19 inches deep. It discharges in turn upon another plate, called the "splash-plate," arranged at an angle of about 45 degrees, and which is 8 inches deep and 46 inches wide. Then the pulp runs over the "apron," a plate 3 feet deep and 50 inches wide. The arrangement just described (and illustrated in Fig. C) serves to give an extra amount of amalgamating surface without taking up much space. From the apron the pulp passes into a small transverse trough, and then goes through two openings, which deliver it to the "distributors," which in turn allow it to pass through on to the sluice-plates. (See Fig. D.) The "distributor" consists of a copper plate punched with holes 1 inch apart, and serves to break up the pulp and to scatter it evenly over the plates which follow. The sluices have a slope of $1\frac{1}{2}$ inches per foot and the apron $1\frac{1}{4}$ inches per foot. The former are $14\frac{1}{2}$ inches wide and 11 feet long. They deliver their burden to another, a single sluice, 14 inches wide and 6 feet long. From the last the pulp goes through a well or mercury trap before passing over a launder for delivery to the concentrators.

Plates

The whole arrangement of the plates is lacking in common sense and is most unpractical. That it is scarcely defensible is fully recognized by the manager, who had to take the mill as it was, but who intends to have a very different arrangement in the new plant which it is proposed to erect. The bad arrangement of the amalgamating tables is a universal defect of the mills of this region, and will be again discussed later on.

Clean up

The general clean-up takes place once a month. The inside plates are then taken out of the mortar and scraped. The battery sands are treated in a barrel where the grinding is assisted by the addition of scrap iron. After 8 or 9 hours quicksilver is introduced, and the charge is retained for 4 hours more. The aprons and splash-plates are dressed whenever their surface becomes hard. Occasionally very finely divided sulphurets collect and have to be brushed off. When crushing such ore as is comparatively free from valuable pyrites and containing gold that is easily caught, the mortar will arrest over 90 per cent. of the total obtained by the entire mill. The aprons and splash-plates are then only cleaned up once a month, and the sluices once a week. When treating sulphuret

Saving

ore,—that is, millstuff containing $1\frac{1}{2}$ to 3 per cent. pyrites,—about 70 per cent. of the total saving is accomplished inside the mortar, and of the remaining 30 per cent. half is caught by apron and splash-plate, half by the sluices. When crushing such ore the aprons are cleaned off partially every other day and the sluices daily.

Tables

Settling Boxes

From the concentrators the waste goes outside the mill proper to another building, where it passes through a tailings plant. The tables are in 8 sections, having a total width of 115 feet and a depth of 18 feet. They are covered with thin canvas, that variety known as 10-ounce Arctic duck. Before flowing over the tables the pulp is roughly sized by means of settling boxes; the heaviest material then goes to the four central divisions. Below the tables there is a series of setting pits which is cleared up at intervals of from two weeks, the uppermost, to six months, the lowermost. The "heads" are shoveled into a box and washed by a running stream on to a Woodbury concentrator, having 11 partitions. The concentrates thus obtained are found to be in an extremely fine state of subdivision. To prevent loss by their suspension on the water running away, care is taken to keep the concentrates under water as much as possible. They can be seen to float in the receiving box under the concentrator belt, but from here they are run through a pipe which issues under water in a tank lower down, where they settle. A saving of $15 per month has been made by the prevention of loss through suspended slimes.

Concentrates

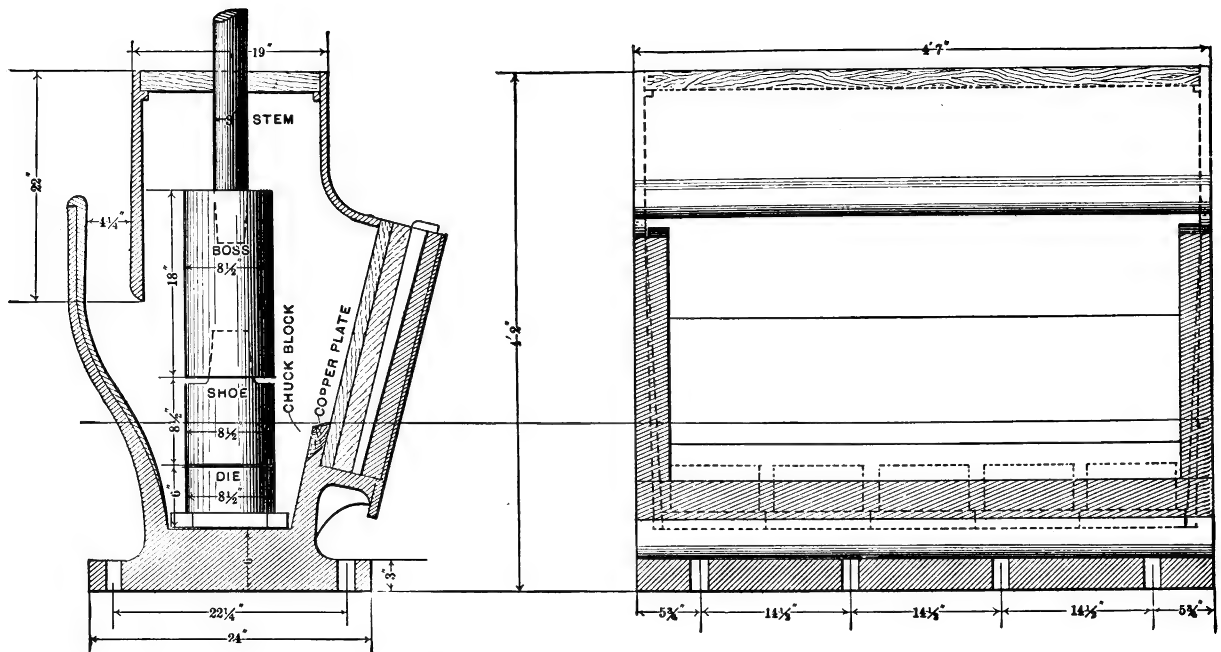
The tailings plant gives one-quarter of the total yield of concentrates; thus, of the last 15 tons obtained, $3\frac{1}{2}$ tons came from here, and $11\frac{1}{2}$ tons from the upper mill. The value per ton varies, usually those from the tailings plant are the richest, but occasionally they are poorer than the average of the upper mill.

Labor

This plant requires one man's labor; he is paid $75 per month. The canvas costs at the rate of $15 per month.

Shoes & Dies

Iron shoes and dies are used at this mill. Good and cheap castings are obtained from the neighboring foundry (Knight's) at Sutter Creek. One reason given for the preference for iron over steel is that the latter wear longer, and therefore too much amalgam is locked up among the dies during the period which elapses before they are changed. In the crush-



Mortar for an Amador Stamp Mill.

discharge less than the height of the drop, the former being 5 inches and in the latter 6 to 7 inches. It was found that when the dies became worn (and the issue thereby deepened) more gold was saved inside the battery. It became desirable to perpetuate such favorable conditions. The lip of the mortar was therefore heightened by the device known as the "chuck-block," a wedge of wood extending along the whole length of the front interior of the mortar. The discharge being thus increased the stamp worked in a greater depth of water, the splash became much less violent, and conditions were obtained which rendered possible the use of an inside amalgamating plate. Previously a plate could not be employed to any purpose because the shallowness of the mortar compelled it to be placed so near to the dies that its surface was continually being scoured by the violent splash of the pulp. Thus from the purely Californian type the Amador mill has made an approach to the Gilpin County (Colorado) pattern. However, even in the case of the deep discharge (13 to 15 inches) and long drop (16 to 18 inches) of the Colorado mill the latter exceeds the former, and the stamp is lifted entirely out of the water.

Chuck Block

Plate

The question here presented is a most interesting one. When the stamp strikes the surface of the water in the battery there is a certain resistance offered by the passage from air to water. This is largely a theoretical consideration, but in practice the chief effect produced by not lifting the stamp free of the water is to diminish the force of the discharge. Instead of a violent, irregular splash there is produced a pulsating, wave-like movement, which results in making the issue of the pulp through the screen less violently intermittent, but more continuous, and it allows a better opportunity for the settling of the particles of gold upon the inside plate and to the bottom of the mortar.

The use of the chuck-block (see drawing of a typical Amador mortar) also enables the millman to regulate the issue and to prevent, to some extent at least, that wide difference between maximum and minimum depth, which is due to the wearing down of the dies. At the South Spring Hill two chuck-blocks are used, one being 6 inches and the other 7 inches high. The former replaces the latter as the dies get worn down.

Chuck Block

When the dies have lost 3 inches, a false bottom, made of steel and 3 inches thick, is placed underneath them, thus restoring the former height of the issue. At the Wildman mill an endeavor is made to maintain a uniformity in the discharge by using chuck-blocks of various thickness, from 4 to 7 inches. At the Kennedy the chuck-block is made in sections, bolted together. The uppermost part, which carries the copper plate, is 2 inches thick; the others are each 1¼ inches. The maximum height is 7 inches. As the dies wear down the discharge is maintained as uniform as possible by removing sections of the chuck-block.

Amalgamation.—The proportion of amalgam saved inside the mortar as compared to that which is arrested on the plates outside will, of course, differ with the changing character of the ore treated. It will also depend largely upon the depth of discharge and the kind of screen in use. A deep issue will tend to arrest the gold inside the mortar at the expense of the crushing capacity. The same result will be produced by a fine screen.

Amalgam

At the South Spring Hill about 55 per cent., or rather more than one-half of the amalgam, comes from the inside of the mortar. No blankets are used at this mill. The tailings are sold to outside parties for $15 per month and 15 per cent. of the gross yield.

At the Wildman more than three-quarters, or from 80 to 83 per cent., of the total amalgam is arrested inside the mortar. At the Kennedy about three-quarters of the amalgam comes from the clean-up of the inside of the battery.

Concentration.—It is the usual practice in Amador, as elsewhere in California, to use two belt concentrators for each five stamps. The Frue vanner is most commonly found in the mills. At the South Spring Hill three kinds of concentrators are used, 8 Frue vanners, 2 Woodbury, and 2 Triumph machines. The last mentioned are said to require very frequent attention. The Frues are preferred.

Concentrati

This mill produces nearly 1½ tons of concentrates daily. At the Wildman mill there are 8 Frues and 4 Triumphs. The former are preferred because they require less frequent attention. This plant yields 1 ton of concentrates daily. At the Kennedy there are 18 Frues, or two machines more than the

ordinary allowance of two concentrators to five stamps. The addition of the extra vanners has proved most satisfactory. The Frue is a machine you can not crowd, and the distribution of the concentration over three, instead of two, machines allows of better contact between the belt and the pulp. This plant produces from 60 to 72 tons of concentrates per month as the result of crushing from 2,900 to 3,150 tons of ore. This is at the rate of about 2¼ tons of concentrates per day.

+ *The Amalgamating Table.*—In an earlier portion of this chapter reference was made to the bad arrangement of the amalgamating tables which prevails in the mills of this as in those of most of the Californian gold-mining districts. The following figures will indicate this feature:

Mill.	Aprons.			Sluices.		
	Length.	Width.	Slope per foot.	Length.	Width.	Slope per foot.
Gover	3 ft. 0 in.	4 ft. 2½ in.	1¼ in.	11 ft.	29 in.*	1½ in.
South Spring Hill	2 " 0 "	3 " 10 "	1⅓ "	16 "	26 "	1⅓ "
Wildman	2 " 0 "	3 " 9 "	1⅜ "	14 "	28 "	⅞ "
Kennedy	2 " 6 "	3 " 10 "	1 "	10 "	28 "	1½ "
Keystone	10 "	4 " 4 "	¾ "	10 "	30 "	1½ "

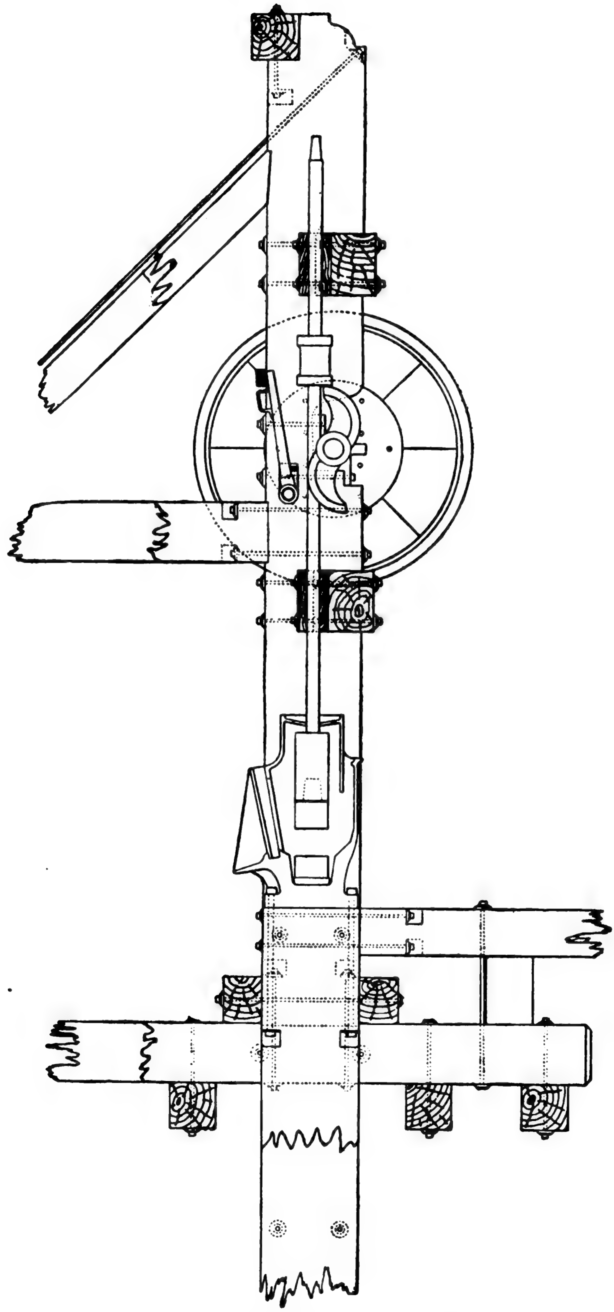
It will be seen that in each case the wide apron-plate, placed immediately outside the mortar, has a short length and is succeeded by two narrow and long sluice-plates. The sense of this arrangement is not obvious, but it is rarely questioned and is almost universal in the mills of California. It is only another illustration of "that everlasting monkey in man," by virtue of which Jones copies Thompson's mill because Thompson erected his mill after the pattern of Smith's. Smith's was considered the best mill in the country, for, did not his mine turn out a bonanza, and was not the machinery built by a well-known firm in San Francisco?

It is a serious matter, however, that the stamp mills of California, otherwise easily the best of those in use to-day, should be spoiled by such an obvious error. The gold caught on the apron consists of the heavier particles whose weight prevents them from traveling further down the tables; the finer particles are not so easily arrested, but are supposed to be caught

* In every instance subdivided into two equal divisions.

upon the sluice-plates. That which is saved on the apron —mostly in the first foot of its length—can hardly escape, but that which is arrested by the sluice-plates is obtained in spite of, rather than by reason of, the methods adopted. The quantity of pulp which passes over a surface 4 feet wide is made to pass over another surface 28 inches wide, the water and crushed ore are crowded into one-half the space and therefore must flow at twice the speed. It is proposed to save gold particles more finely divided than those already caught by the apron, but under conditions a great deal more unfavorable to amalgamation. One would naturally suppose that the sluice-plates would be placed at a less slope than the aprons, so that the flow of the pulp might be moderated. It is not so; in most cases the inclination of the sluice-plates is steeper than that of the aprons. The former, therefore, act as launders to convey the pulp to the concentrators, but it is absurd to consider them as intelligently planned gold-saving appliances. The California stamp mill will always be characterized by a very serious blemish while it retains so unscientific and so unpractical an arrangement of its amalgamating tables.

In concluding this description of the mills of Amador County, it will not be out of place to refer to the general character of the work done in the district. The costs of mining and milling are uniformly low, but yet not quite so low as the figures often quoted would lead one to suppose. It is not unusual to see the assertion made in a prospectus or a newspaper to the effect that the total cost of extracting the gold from the ore, including not only mining and milling, but also general expenses, interest on machinery, repairs, etc., is $2.50 per ton, or even less. One of the largest mining concerns ever operated in this district is the Plymouth, a mine 1,600 feet deep, which paid several millions in dividends. In 1887 the average yield was $7.57 per ton. In 1888 it was $6.18. The cost of mining was $2.34, of milling 39 cents, of concentration and reduction of sulphurets 17 cents, and general expenses 17 cents, making a total of $3.07 per ton. This is a fair instance of what can be done by a large mine in this district. In the case of three representative mining companies now working profitably with mills of 20, 40, and 30 stamps, respectively, the total costs are $2.35 to $3.45, $3.50 to $3.75,



Section of an Amador Stamp Mill.

$3.10 to $3.25, per ton of ore. When once a mine is developed to the extent of having enough ore in sight to supply a 40-stamp mill for one year it may be taken that the total cost per ton, including a proper proportion of exploratory dead work, interest on plant, repairs, etc., need not be over $3 per ton. The cost of mining would be $1.75 to $2.25, of milling 20 to 35 cents (not including water-power, or 35 to 50 cents, inclusive), concentration and chlorination 15 to 25 cents, general expenses, etc., 20 to 30 cents.

It may therefore be said, by way of conclusion, that while the mills of Amador County are by no means perfect, yet the methods of mining and milling pursued in this district have done much to build up the reputation which California has so long enjoyed for leading the way in the matter of the economical extraction of gold from its ores.

CHAPTER V.

THE PROFITABLE WORKING OF LARGE BODIES OF LOW-GRADE ORE.

The first mining excitement occurring in this region is to be credited to the year 1875, when placer discoveries were made at Custer City, at that day the frontier post and the starting-point for prospecting parties. In June of the following year the Wheeler Brothers found rich gravel in Deadwood Gulch, between the sites of the present towns of Deadwood and Central City. They, and others who came later, cleaned up that November, pulled up stakes and sold their claims. A party of about 30 men carried the result of the season's labors —namely, gold of a value of from $800,000 to $900,000—to the First National Bank at Cheyenne.

At that time, early in the story of the restless development of the Rocky Mountain region, the outcrops of quartz veins were found by the pioneers, but the California and Montana miners who were among them tested the value of the ore by means of panning, and recovering only from $3 to $10 per tons they ridiculed the idea of operating on material of so low a value.

On April 7, 1877, a 5-stamp mill for the Racine Company arrived at the lower end of what is now Lead City. On April 20, the first clean-up took place. On May 1 the second stamp mill, Pearson's, reached Central City.

The history of the Homestake Mining Company begins with the arrival, in the fall of 1876, of representatives of Haggin & Hearst, of San Francisco. In January, 1877, Sam. McMasters, another agent of the same syndicate, came; in February some of the mines were purchased, and on October 23 the Homestake No. 1 claim was bought from Manuel Brothers. In July of the following year the first and only assessment

was levied. It was at the rate of $1 per share, and afforded the $200,000 required for the erection of the first mill. This was of 80 stamps, and was brought in on a bull train. It now forms part of the present Homestake mill. As the magnitude of the ore deposit became proved by exploration, the milling capacity was increased, until the Homestake became a name associated with the successful operation, on an enormous scale, of large bodies of gold ore of very low tenor.

The Black Hills, geologically an Archæan island flanked by later sedimentaries, topographically a group of granite peaks surrounded by clustering foothills, forms the only important mining region of South Dakota. Extensive and important mining operations are largely confined to what is known as "the Belt," extending from Whitewood Creek to Deadwood Gulch, through the linked settlements of Lead City, Terraville, and Central City.

The ore occurs in the form of large bodies of quartzified chloritic schist conformable to the structure of the country and forming a portion of it. The area of territory which has been proven profitably gold-bearing is about a mile and a half long by half a mile wide. The width of milling ore varies from 50 to 400 feet. Huge excavations have been made along the outcrop of the lode, the ore going direct to the mill, while the waste material is sent down into the mine to fill up the underground stopes.

In 1888 there were 660 stamps dropping on the millstuff broken upon the Belt; to-day the number is 550. The richer ore bodies of the De Smet and Caledonia mines have given way to material too low in gold contents to be profitably worked. The mills of the Homestake Mining Company (shown in the accompanying illustration), however, show progressive enlargement, as is indicated in the accompanying table (No. 1), which gives the names and sizes of the various plants in this district.

Referring to this table, it may be added that the Homestake was an 80-stamp mill when first built, and it is still often spoken of as "the 80 mill." The Highland is now being increased from 120 to 140 stamps. The Deadwood and the Golden Terra were consolidated six years ago, the 80 stamps of the Terra being placed behind the 80 stamps of the old

Deadwood-Terra Open Cut.

Deadwood mill. The plant is now known as the Deadwood-Terra. The De Smet ceased work in 1892, and the Caledonia in 1893. The Columbus is a new, small plant, treating ore from the outskirts of the Belt at Central City.

TABLE No. 1.

THE STAMP MILLS OF THE BELT, SOUTH DAKOTA.

Name.	Date of erection.	Location.	Number of stamps. 1888.	Number of stamps. 1895.	Owners.
Homestake . . .	1878	Lead City,	80	100	The Homestake Mining Company.
Golden Star . . .	1879	Lead City,	120	160	
Highland . . .	1880	Lead City,	120	140	The Highland Mining Company.
Deadwood . . .	1879	Terraville,	80	160	The Deadwood-Terra Mining Company
Golden Terra . .	1880	Terraville,	80		
Father de Smet.	1878	Central City,	100	100	The Father de Smet Mining Company.
Caledonia	1879	Terraville,	80	80	The Caledonia Mining Company.
Columbus	1894	Central City,	. . . .	10	. . . .

Before plunging into an account of the milling methods it seems needful to apologize for undertaking the task in the face of the very excellent description prepared by Prof. H. O. Hofman, which appears in Vol. XVII of the *Transactions of the American Institute of Mining Engineers.* My excuse is that during the interval of seven years since that article was prepared some changes have been made at the mills, and, furthermore, I felt that this book would be incomplete without some reference to the methods of so famous a milling center as the Black Hills. To escape unnecessary repetition, however, I have avoided dealing with certain aspects of the milling practice, which are so fully handled by Prof. Hofman, in the paper above referred to, as to render my account of them a work of supererogation.

The immense size of the ore bodies from which the mills get their daily supply is well suggested in the accompanying photograph of one of the big open cuts. Another illustration shows the distribution of the Homestake mills, and the general appearance of the Belt in the vicinity of Lead City.

The ore as it comes up from underground is dumped into the rock-breakers. Formerly, until 1889, it went to the mill and was unloaded upon grizzlies, from which the coarser portion went to the crusher floor. The Blake crusher was at that

time in use, but the successful trial of the Gates machine, at the Caledonia mill, led to the introduction of the latter all over the Belt and to the entire replacement of the former. Those in use are as follows:

Mill.	Number of crushers.	Size.
Homestake	3	Gates No. 6.
Highland	2	Same.
Deadwood-Terra	2	Same.
Caledonia	1	Same.
Columbus	1	Gates No. 1.

The first reduction of the ore by the breakers at the mine instead of at the mill is a decided and very obvious improvement. It renders more easy the loading of the cars which transport the ore to the mill; it does away with the unequal strain upon the mill engine when the rock-breaker, as is too often the case, is not worked by a separate source of motive power, and it eliminates the larger portion of the dust, which is such a nuisance not only to the men at work, but also to the machinery of the mill. Furthermore, it enlarges the capacity of the ore-bins, and does away with the necessity of having two series, one for the coarse above the crusher floor, and one for the fines below it.

By having a spare breaker, as is the case at the Homestake shaft, where only two out of the three are in use at any given time, there need never be any interruption to the regular passage of the ore as it comes out of the mine, through the crushers, into the mill cars.

The larger receiving capacity of the Gates and its crushing power render it preferable, in large mills certainly, to the Blake. The idea of first reducing the ore at the mine is common in California, the breaker at the mine being sometimes followed by a further reduction of the ore by a second breaker at the mill itself. This practice is good, because the relieving of the stamps of the hard work of first crushing aids rapid pulverization in the mortar and gives conditions more favorable to successful amalgamation.

In the accompanying table (No. 2) will be found the chief figures telling of the milling practice. The table has not the variety which would be evidenced in other districts, because the management of the Homestake also controls the neighboring mills, with a consequent tendency toward a general uniformity of methods.

Table No. 2.

INDICATING THE MILLING PRACTICE OF THE BLACK HILLS DISTRICT, SOUTH DAKOTA.

Name of mill.	Number of stamps.	Weight of stamp.	Number of drops.	Height of drop	Depth of discharge.	Variety of screen.	Percentage of concentrates.	Ore crushed per stamp per 24 hrs.	Capacity of entire mill.	Wear of screens.	Consumption of water.	Retort percentage.	Fineness of bullion.	Number of concentrators.
		Lbs.		In.	In.		Per cent	Tons	Tons.	Days.	Miner's in.	Per cent	Per 1000.	
Homestake	100	850	85	9½	9 to 11	Slot No. 8.	2	4	400	7	1½	34 to 38	815	6
Highland	140	850	85	9½	9 to 11	Slot No. 8.	2½	4	560	7	1½	35 to 37	815	8
Golden Star	160	850	85	9½	9 to 11	Slot No. 8.	2	4	640	7	1½	34 to 38	815	8
Deadwood-Terra .	160	850	88	8½	9½ to 11½	Slot No. 8.	none.	4¼	680	9	1⅔	30 to 35	830	none.
Columbus	10	850	90	8	8 to 10	Wire, 40 mesh.	6	3½	35	10	1	28 to 48	825	1

Referring to the comparative table, the following notes will be pertinent. The total dropping weight of the stamp in all the Homestake mills was originally 850 pounds, but the tappets and bosses have been made heavier so as to make the weight now approach 900 pounds. The number of drops per minute varies, of course. I found it to average nearer 88 than 85, the latter being the figure given to me by the millman. The height of the drop appears to have undergone a slight increase since 1888. At the Deadwood-Terra it was 9 and 9½ inches until quite recently. The reason given for the change is the idea that a longer interval between the drops permits the stamp to turn upon the ore, a purely theoretical consideration quite secondary to the fact that the slightly increased interval is found in practice to diminish breakages by preventing the horn of the cam from striking the tappet too soon.

Stamps weight Drop Speed

In the matter of the depth of discharge the variation is due to the wearing down of the dies. The importance of this factor in gold milling is universally underestimated. At the Homestake a serious effort is made to obtain some approach to uniformity in the issue by the use of chuck-blocks of different sizes. The chuck-block serves as a false lip to the mortar; it is in the form of a piece of 2-inch plank bolted to a 1¾-inch board, the latter projecting about 2 inches beyond the former, to which a copper plate is attached. The replacement of the 2-inch plank by ¼-inch iron, a method introduced some years ago, has been abandoned since the slight increase (1⅝ inches) in the distance between the chuck-block and the shoe was not needed in a mortar whose chief characteristic is its narrowness and whose primary intention is to promote rapid crushing. In the old Coledonia there were two inside amalgamating plates because the design of the mortar permitted it and the character of the particular ore suggested it. In the Homestake mills, however, there is only one inside plate which is of plain copper and 5 inches wide. When new dies are introduced they are accompanied with the use of a chuck-block 7 inches high, making the distance from the bottom of the screen to the top of the die about 9 inches. After two weeks have elapsed this 7-inch chuck-block is replaced by one only 5 inches high, the difference between the two being approximately equivalent to the wearing down of the dies.

Plates

Chuck Block

The copper on the first chuck-block is straight, on the other it is slightly curved and mounted on thicker wood so as to bring it nearer the stamp. The aim is to have the bottom of the chuck-block level with the bottom of the shoe. After from four to six weeks the dies are worn out, and at that time the discharge has reached a maximum of about 11 inches.

Chuck-Block

At the Deadwood-Terra three chuck-blocks, 5, 6, and 7 inches high, respectively, are in use. It is intended to keep the top of the die about level with the bottom of the chuck-block. The discharge increases from a minimum of 9 inches to a maximum of over 11 inches. In the Columbus mill two inside plates are employed. The front one is 5 inches wide, and is attached to a 5-inch chuck-block. The back one is 8 inches wide, and is fastened to the mortar itself. Although the latter has only 12 inches of inside width, both plates do good work. The violent agitation of the pulp and the scouring of the surface of the plate, which might be expected to occur in so narrow a mortar, are minimized by the fact that the issue is so deep that the stamp is never lifted clear out of the water, but produces a steady pulsation rather than an irregular splash against the screen and the inside plates. The Columbus mill, however, crushes less ore than those on the other side of the hill. The mortars are arranged in pairs, with a passage-way between each pair. The automatic feeding of the ore is done by Hendy "Challenge" ore-feeders in four of the mills (the De Smet, Golden Star, Homestake, and Deadwood-Terra), and by Tulloch feeders in two (the Highland and Columbus). The relative merits of these two machines are now well recognized, the main points of distinction being that the Hendy is much the more expensive, but it is also the most automatically perfect, and can treat wet ore as well as it can dry millstuff, for feeding which the Tulloch is not so well adapted.

Screens

In the matter of screens the mills under the Homestake management are uniform in the use of No. 8 diagonal slot-punched Russia iron, equivalent to 30-wire mesh. They usually break before they become worn out, owing to the Russia iron being brittle along the edges of the rows of slots. They are not, however, in any case permitted to remain in

use until worn out, because the openings would be so enlarged as to make the crushing too coarse. At the Homestake mills they are never used for more than two weeks, but, as a matter of fact, they are generally thrown out, owing to breakage, after from six to eight days. At the close of their first week of service they are turned upside down. The chief cause of breakage* is the chips from mine timbers which become mixed with the millstuff and impinge against the screen so as to dam up the pulp and expose the punched iron to a pressure beyond its strength. At the Deadwood-Terra the screens last an average of nine days, because the material treated is mostly surface ore, and in such there are less chips, because less timbering is done than in the big underground stopes. At the Columbus mill 30-mesh brass wire is employed. Three sets of screens are in constant use for each battery, and every day one is replaced by another, while the third is undergoing a cleaning. The screens are first dried and then rubbed with a brush such as is used for chinaware, so as to free the wires from adhering material. Formerly No. 6 burr-slot screens were used at the Homestake mills. Then No. 7 came into use, but now the No. 8 smooth slot is claimed to be the best variety. It is stated that wire cloth cannot be used because of the wood chips in the ore, and that when it was tried a few years ago in the Golden Star mill a screen was burst out every forenoon. Aluminum bronze slot screens gave good service, but proved too expensive. It has always been the custom to take out the screens and replace them with new ones before they become actually worn out. To retain them would be false economy, because their retention too long in service means coarse crushing, consequent upon the erosion of the edges of the openings. It is much to be regretted that the above-mentioned chips should render wire cloth impracticable, because with such screens not only is there greater proportionate area of discharge, but, owing to the fact that the wires do not wear so easily, the apertures remain of constant size and it is simple breakage only which brings the life of the screen to a close.

Mercury fed

Mercury is fed into the battery in quantities proportioned to the richness of the ore and regulated by the condition of the amalgam on the apron-plates. At the four principal mills

* Also due to the unusual narrowness of the mortars in use.

the rate at which the mercury is fed can be judged by the accompanying record, covering the two weeks previous to my visit. See Table 3.

Table No. 3.

CONSUMPTION OF MERCURY AT THE HOMESTAKE STAMP MILLS.

Date.	Deadwood-Terra, 160 stamps.		Golden Star, 160 stamps.		Highland, 120 stamps.		Homestake, 100 stamps.	
	Lbs.	Oz.	Lbs.	Oz.	Lbs.	Oz.	Lbs.	Oz.
May 1, 1895	11	5	25	13	15	4	* 9	10
" 2, "	10	2	*17	14	*12	9	12	2
" 3, "	10	0	25	16	15	1	13	0
" 4, "	12	2	26	13	10	10	12	12
" 5, "	* 9	12	25	3	10	6	11	7
" 6, "	10	6	24	8	16	8	12	2
" 7, "	11	11	23	2	17	0	12	8
" 8, "	11	6	24	12	19	3	12	15
" 9, "	11	8	23	13	19	8	12	13
" 10, "	10	14	25	3	18	12	12	13
" 11, "	11	0	23	7	18	8	12	7
" 12, "	10	12	24	6	17	4	11	1
Average per day	10	14	24	3	16	5	12	2

It will be observed that though the Golden Star and the Deadwood-Terra mills crush approximately the same amount of ore, the former uses more than twice as much mercury. This fact is explained by the wide difference in the richness of the ore, for while that crushed in the batteries of the Golden Star averages from $4 to $5 per ton, that which goes through the Deadwood-Terra ranges from $1.50 to $2 per ton.

For the year ending June 1, 1894, the Homestake mill used 2,084 pounds and the Golden Star mill 3,440 pounds, making a total of 5,524 pounds avoirdupois, which at the price obtaining that year, 42 cents, makes the value of the mercury used $2,320.13. During that time 309,210 tons of ore were crushed, so that the consumption was at the rate of about 5 dwts. troy or $\frac{3}{4}$ cent per ton. At the Deadwood-Terra 205 pounds were used in February, 1895, in treating 18,483 tons of ore. It is estimated that 22 per cent. of the amount of mercury used is lost.

At the Homestake Mining Company's mills the water used in the batteries is at the rate of $1\frac{1}{2}$ miner's inches per battery of 5 stamps per 24 hours. This is equivalent to 23,414 gallons per battery, or a little over 3 gallons per stamp per minute. At the Deadwood-Terra it is a little more, at the Columbus a

*Indicates clean-up days.

Interior View of Golden Star Mill.

little less. The quantity of water used is proportioned to the quantity of pulp crushed and its specific gravity, the intention being to so regulate this factor as to produce a slow, wave-like movement over the outside amalgamating tables, and to so thin the pulp as to aid the separation of the gold without having such an excess of water as would rush the crushed ore too rapidly over the amalgamating surface.

In winter the water occasionally runs low. It is then used over again by the intermediation of the two setting dams constructed in the gulch below the mills, the water being pumped back when the mud has settled. The mine water is also often used to supplement the ordinary supply when otherwise insufficient.

CHAPTER VI.

Milling in the Black Hills, South Dakota.

In the last chapter the Homestake mills were passed in review. Their arrangement and operation is of great interest to those engaged in the exploitation of large deposits of low-grade ores, such as are likely to be our main source of the precious metal in the coming century.

In their general arrangement the mills follow a common, well-planned design. The batteries are placed in two rows upon a flat site. In the Father de Smet, erected in the summer of 1878, the 16 batteries are arranged in two rows of eight facing each other and discharging toward the center of the building. This arrangement, convenient in that it brings all the amalgamating apparatus under one view, has nevertheless in practice been found less serviceable than that adopted in all the other plants. In these the batteries are also in two rows, but are placed back to back with ore-bins and feeders distributed in the space between. The cars on arrival at the mill are emptied so as to send half their contents to either side into the rows of ore-bins, the bottoms of which make an angle similar to a flat inverted letter V, as is shown in the accompanying drawing* of the Highland mill. The Father de Smet has the largest bin capacity, obtained, however, at the expense of darkening the amalgamating tables. Mr. Bowie, who designed the mill, states that the ore-bins have at times contained 1,500,000 pounds of ore without injury to the structure.†

At the Highland mill the main shaft runs through the center of the building, over the battery sills, and connects with the counter-shaft immediately behind the stamps. At

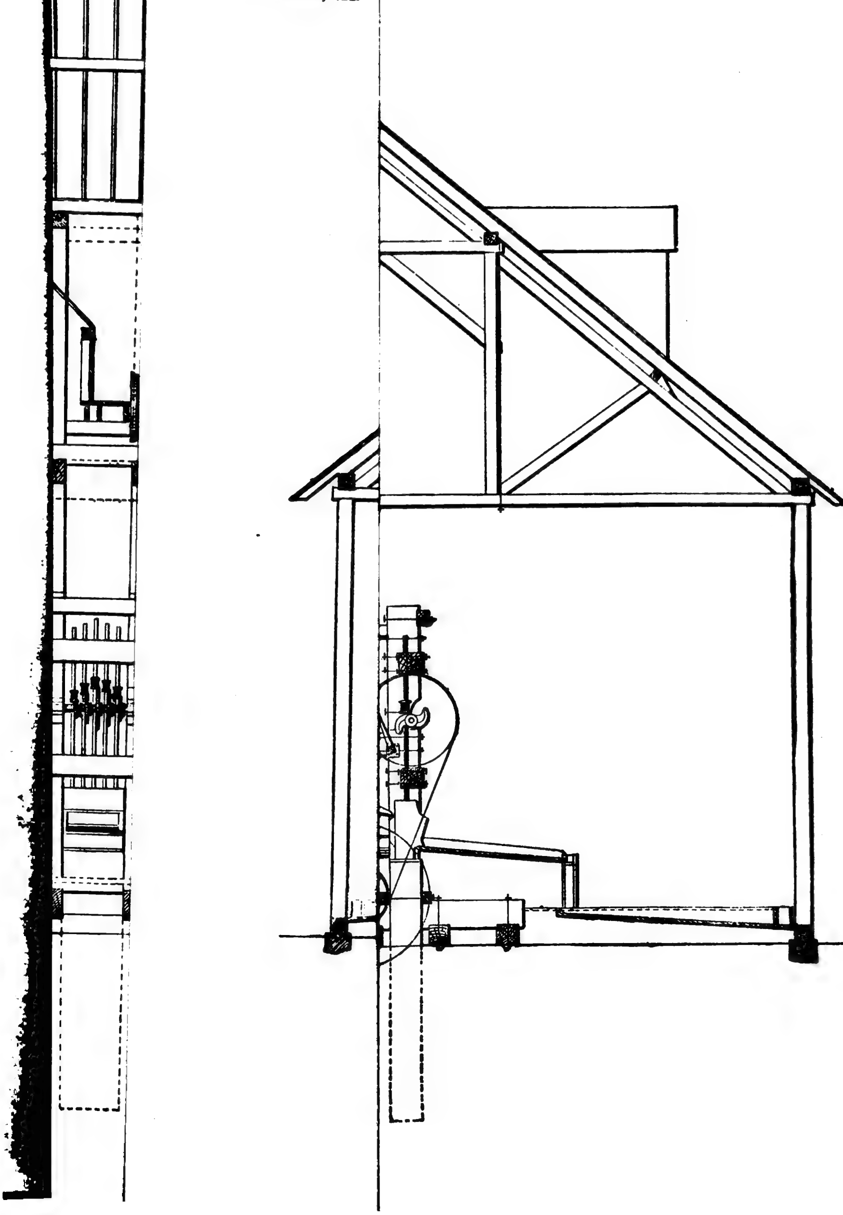
* Which I owe to the courtesy of the builders, Fraser & Chalmers.

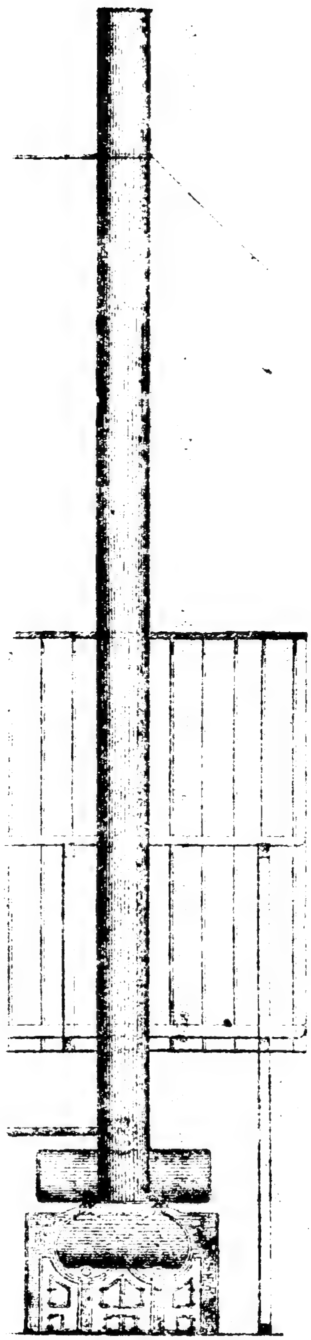
† *Transactions American Institute Mining Engineers*, Vol. X., p. 88.

The Homestake Company's Stamp Mills, South Dakota.

UDINAL AND CR
OF
E HIGHLAN
DEADWOOD, SO. D

BUILT BY
FRASER & CHALME
CHICAGO, ILL.





the Golden Star the driving shaft is placed on an approximate level with the cam shaft, so that the battery belts are nearly horizontal. In the Homestake the line shaft runs direct from the engine through the center of the mill along the battery sills, and the battery belts extend each way at about an angle of 30 degrees. At the Deadwood-Terra the main shaft on one section is a continuation of the crank shaft of the engine, the other takes its belt from this. The counter-shafts are under the feed floor just behind the batteries. Shafting

Of these diverse arrangements that of the Golden Star mill obtains common preference. It is similar to that generally in vogue in California. The arrangement to be seen in the old Homestake mill entails a small first cost, it is simple, and it gives an equal pull either way upon the main shaft, but it is nevertheless not to be preferred to that of the Golden Star. The placing of the counter-shaft immediately under the feed floor and behind the batteries is objectionable, because this is a part of the mill particularly subject to the dust and and dirt surrounding the crushing apparatus; it is inaccessible and inconvenient; it requires the use of tighteners, and it is affected by the vibration due to the falling stamps. The Highland mill uses up three belts while the Star is wearing out one. The arrangement obtaining in the latter places the driving shaft nearly horizontal with the cam shaft, dispensing with tighteners; it renders everything well lighted and easily accessible, and by the use of a framework independent of the battery sills it minimizes the effects of the vibration due to the stamps. Arrangement

When first erected the order of the drop in any two adjacent batteries was: Order of drop

1-5-9-7-3 | 2-6-10-8-4

The pulp used to wash always one way and tended to accumulate at one end. Now it is:

1-7-3-9-5 | 2-8-4-10-6

At the Deadwood-Terra the order in any single battery is 1-4-2-5-3, which corresponds to the last above given. The order 1-5-2-4-3 tends to scour the chuck-block and wear the screen, because two stamps drop almost simultaneously, but, on the other hand, this last arrangement promotes rapid crushing better than any other, and many millmen prefer it.

Saving

In the matter of the saving of the gold-bearing sulphides remaining in the tailings, the mills of the Belt afford no commendable example. The sulphides of the Deadwood-Terra are too low in value to be worth collection, but at the mills on the Lead City side of the hill, shaking tables are in use. They are the familar, very simple and excellent machines known as the Gilpin County bumping tables. The number of them in use is, however, absurdly disproportioned to the amount of material going over them, so that the six concentrators at the Homestake and the eight machines at each of the other two, the Highland and Golden Star mills, must be considered only in the light of a badly planned experiment. At the Columbus there is one concentrator, treating the pulp from 5 stamps, the ore containing 15 per cent., and the concentrator collecting only 6 per cent. because it is overcrowded with pulp.

Concentrates

During the year ending June 1, 1894, the two Homestake mills produced 915,010 pounds of concentrates, whose assay value varied from $5 to $8 per ton. They consist of iron pyrite, arsenical pyrite, and pyrrhotite. The ore contains from 3 to 5 per cent., but only about 2 per cent. of the sulphides are saved. They are sent by rail to the Deadwood & Delaware smelter, just below the town of Deadwood, where they are treated at a charge of half their assay value and converted into an iron matte, very low in copper and rich in gold, which goes to the Omaha & Grant Smelting and Refining Company, at Omaha, for further treatment.

Turning to the process of gold extraction in the various stamp mills, we find that it is carried on in the mortar itself, on apron-plates, by means of traps and is finally partially supplemented by an inadequate effort at concentration.

The mortar becomes an amalgamating machine by the addition of free mercury, as already described. From the mortar the pulp is discharged through the screens and drops 6 to 10 inches upon the apron-plates. This drop serves no purpose A splash-board, placed so as to face the discharge, receives and breaks the fall of the issuing pulp. This prevents the sand from scouring the surface of the apron-plate.

Tables

In the Golden Star and Homestake mills the aprons are 10 feet long by 4½ feet wide. In the Highland the length is 2 feet less. Two aprons deliver their pulp to one tail-plate

having a size equal to the apron (the general arrangement is well illustrated in the photograph of the interior of the Golden Star mill. See page 85). Both apron and tail-plate have an inclination of 1½ inches per foot. An attempt has been made to work the lower plate with a less slope, but the gravity of the pulp prevented the plate from clearing itself. The millmen complain that the lower plate is hard to keep in order, because of the small amount of amalgam which it carries on its surface. The remedy would be to clean it less often, or to use an electro-plated silver surface. Amalgam is the best thing for keeping plates in order, and is superior to all the chemicals in creation.

All the plates are of plain copper. In the Highland mill the launders have their bottoms covered with copper. The plate which goes inside the mortar is cleaned up twice per month; so also the tail-plates. The aprons are cleaned and dressed every morning. The tail-plate is also dressed each day.

At the Deadwood-Terra the aprons are 11 feet long by 4 feet 8 inches wide. The sluice or tail-plate is 8 feet long by 16 inches wide, forming an absurd apparatus for arresting gold. At the Columbus the apron is 14 feet long by 4 feet 3 inches wide. The inclination is 2 inches per foot.

At all these mills there are traps or other similar devices for arresting escaping mercury and amalgam. In the Golden Traps
Star, for instance, there is a 2-inch riffle or trap at the bottom of the apron, and at the head of the tail-plate there are two deep traps with a drop of 18 inches. The first-mentioned riffle or shallow well is said to do the best work because the pulp which goes over it is flowing smoothly and the conditions favor the separation of the amalgam and its arrest. In the case of the subsequent drop-traps the pulp is so agitated by the greater speed of its passage and the depth of the drop that opportunity for settling is less. These traps are cleaned up every two weeks, the accumulated pyrites are shoveled into buckets, and then passed into a pan which extracts all the free amalgam. The residues from the pan are then fed into a particular 5-stamp battery, provided with a No. 10 slot screen. They are passed through this battery twice and are then sent to the smelter, their final assay value being about $38 per ton.

The above suggests the Australian practice of mercury wells, particularly employed at Clunes, with the obvious difference that the Homestake traps are not supplied with free mercury. It is claimed that if sufficient mercury is fed into the battery no free gold should escape, and the mercury in the traps would merely serve to thin the amalgam and make it easier of escape. The traps catch concentrates and amalgam only.

At the Homestake mills about one-half of the total amalgam comes from the inside plate. The traps catch about 1 per cent. of the total. At the Highland mill 4 to 6 pounds of amalgam are obtained from the traps at each clean-up. At the Deadwood-Terra quite 70 per cent. of the total amalgam comes from the inside of the battery.

An effort is made to maintain the battery water as near 70° F. as possible. In the winter months the exhaust pipe of the engine is turned through the supply tank and keeps the water warm. If the temperature is raised too high it is found that the mercury becomes too mobile and runs down the plates, leaving the amalgam too hard for good service. Very few chemicals are used. At the Golden Star mill only 10 pounds of potassium cyanide are consumed per annum. It is found advantageous to wash the plates with a weak solution of salt and sulphuric acid, a handful of salt and half a teacupful of acid in 2½ gallons of water.

The concentrating apparatus, such as it is, has been described already. Its inadequacy is recognized and experiments are now being made with jigs which promise well. Several years ago two blanket houses were in use; the blanketings were worth from $20 to $30 in assay value, and were obtained by employing Brussels carpets.

The best comment to offer on the existing methods is to state the fact that a Cornishman a few miles below the mills has been successfully treating, by means of two simple piston jigs, the tailings carried down in the creek. His success has attracted the attention of the Homestake management, and induced the commencement of the experiments above referred to.

The various castings required in the mills, such as cams, tappets, dies, and even mortars, are made on the spot at the foundry controlled by the Homestake management. In the

matter of breakages it may be stated that at the Deadwood-Terra mill 29 stems were broken in April, the ordinary average being 20 per month. At the Golden Star the average is 40 per month. The cast-iron cams, made locally, do not give such good service as steel cams imported from the outside, but other business considerations cause the management to prefer them. The shoes come from Chicago and cost 2 cents per pound, to which the freight of 85 cents per 100 pounds must be added. The dies, homemade, are estimated to cost at the rate of 2 cents per pound. The latter are made of iron slightly softer than that of the shoes, and therefore the conditions for good service, in so far as relates to the relative hardness of the metal in the shoe and die, are obtained.

Chrome steel shoes did not give as good service as the cast iron. The chrome steel dies wore better than the iron, but they were rejected on account of their greater cost, at that time 6 cents per pound in Brooklyn, to which freight must be added. Shoes made of ferro-aluminum gave good results. In this connection it may be mentioned that statements regarding the service of shoes and dies made of particular mixtures of iron or steel are not always reliable because, first, of the varying quality of succeeding shipments of such material, and, secondly, the fact that their service is largely dependent upon whether both shoes and dies are made of the particular metal or whether the shoe is used with a die of a different metal, or *vice versa*. The chrome shoes at the Homestake wore smoothly and cupped slightly. I may here mention the observation, made by Mr. A. L. Read, of the Golden Star mill, that the slight hollowing of the shoe helps the crushing capacity of the mill by tending to hold the pulp under the stamp instead of splashing it out. This does not, of course, refer to irregular cupping, but simply to an even, gentle hollowing out of the face of the shoe.

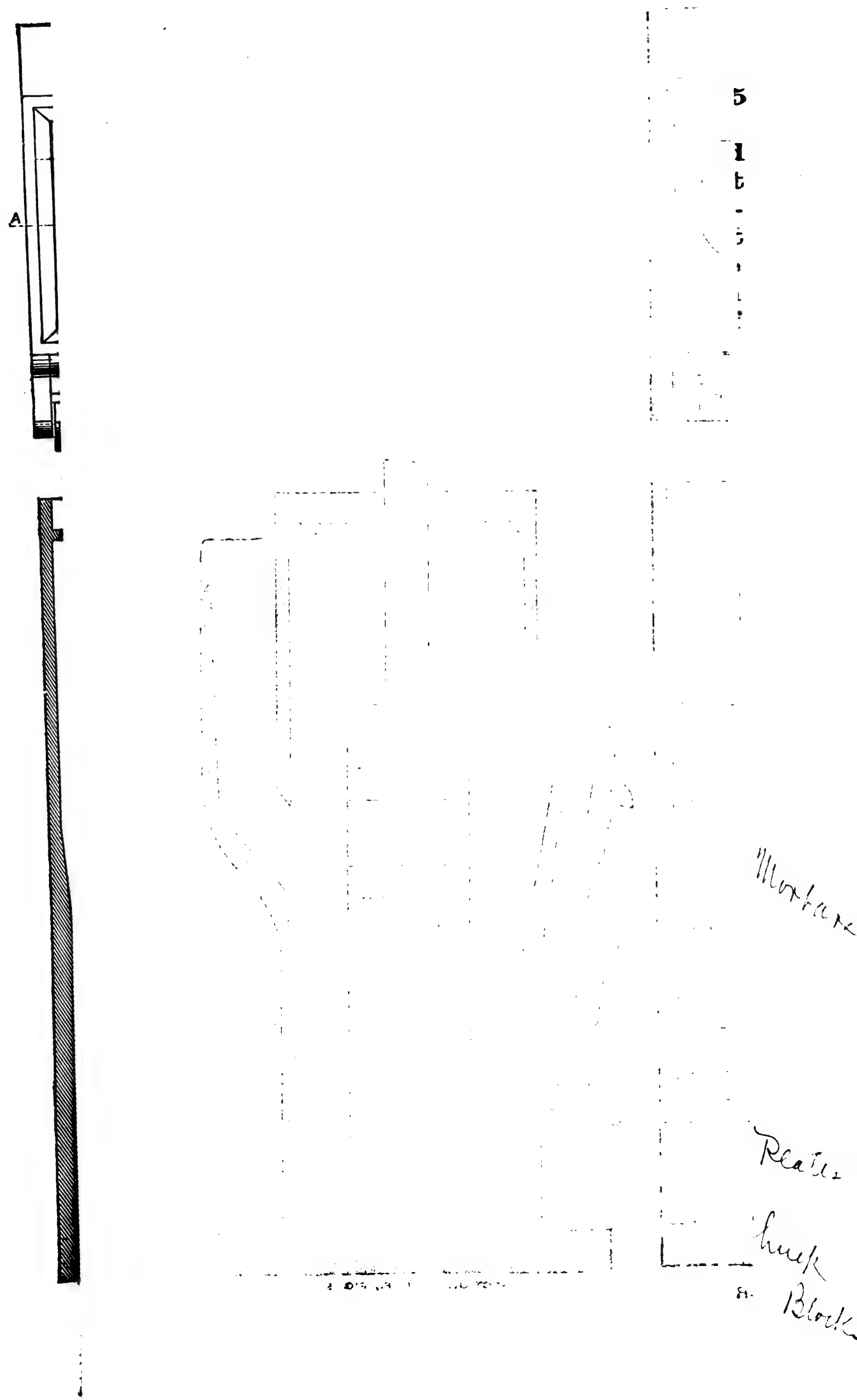
The guides in use are the invention of Edmund Major, formerly a carpenter in the employ of the company. They are made of maple and are capable of convenient adjustment so as to counteract the tendency of the stem to work away from the side on which the cam is placed. One stem can be removed without taking down the entire series of guides belonging to any single battery.

Revolution of Stamps

Key tappets, with two keys, are in general use. The stamps of two neighboring batteries revolve toward one another. I noted that it took from five to nine drops to enable the stamp to make a complete revolution. The variability in this respect was mainly due to the quantity of grease upon the surface of the cam.

The Homestake Mortar.

The work of the mill used to be checked, not by the regular taking of pulp samples, but by the rough testing of the ore coming from the mine by the sampler, a man whose business


A
5
Mortare
Reate
Lock
Block

Revoluti
Stam

it was by careful panning to estimate the amount of free gold in the millstuff. He made a daily report and by that report the mine foreman was guided in the distribution of his stoping activity. It has always been the aim of the management to maintain a uniform monthly output. It is the practice now to take samples of the tailings in the afternoon of each day at each mill. They are taken every hour for a period of five hours by the use of a dipper placed at the foot of each apron-plate. The gold contents are determined by fire assay. Nothing more careful or more intelligently systematic is ever done with a view to determining the actual extraction accomplished in the mills.

The annexed plan and section, which I owe to the courtesy of the makers, Frazer & Chalmers, Limited, of the mortar in use at the Homestake mills, will be of service in indicating the conditions under which the inside amalgamation is carried on. The pattern was changed about 10 years ago, the mortar being made narrower and the issue deeper. The latter was also further increased by the use of chuck-blocks. The inside width of the mortar at the level of the discharge is 13 inches. At the Columbus mill it is 1 inch less. For purposes of comparison it may be mentioned that at the Pearl mill, Bendigo, the inside width is 15 inches, at the North Star mill, Grass Valley, 17½ inches, and at the Hidden Treasure mill, Black Hawk, it is 24 inches.

The accompanying reproduction from photograph represents the latest design of this type of mortar. The makers inform me that a number of changes have been made in its construction. The original Homestake mortar had outline dimensions as follows: Length of base, 4 feet 8 inches; width of base, 2 feet 4 inches; height, 4 feet 11½ inches; weight of mortar, 6,500 pounds. The last-constructed mortar weighs 7,300 pounds, and its length of base is 4 feet 8¾ inches; width of base, 2 feet 4¼ inches; height, 4 feet 10¼ inches. The latter is provided with cast-steel false bottoms 2½ inches thick; also with cast steel liners seven-eighths inch thick along the sides of the mortar, and a similar lining one-half inch thick upon the feed opening. It is provided upon the inside with copper plates one-fourth inch thick and furnished with chuck-blocks, each of which is copper lined. The chuck-blocks are made in

Mortar

Plates

Chuck Block

Stamp weight

a series of three, 6 inches, 8 inches, and 10 inches deep, respectively. The tendency is to depart from the original weight of the stamps, 850 pounds, and to use 900 pounds and more.

Table No. 4.

SHOWING THE LABOR EMPLOYED IN THE PRINCIPAL STAMP MILLS.

	Deadwood-Terra. 160 stamps.			Homestake. 100 stamps.			Golden Star. 160 stamps.			Highland. 120 stamps.		
	Number.	Shift, hours.	Wages, dollars.	Number.	Shift, hours.	Wages, dollars.	Number.	Shift, hours.	Wages, dollars.	Number.	Shift, hours.	Wages, dollars.
Foreman	½	A	$7.00	⅓	B	$8.00	⅓	B	$8.00	⅓	B	$8.00
Millwright	1	12	3.50	1	12	4.25	1	12	4.25	1	12	4.25
Pipefitter	..	..	..	½	C	3.50	½	C	3.50	..	D	..
Enginemen	2	12	3.00	2	12	3.50	2	12	3.50	2	12	3.50
Firemen	2	12	2.50	2	12	3.00	2	12E	3.00	2	12	3.00
Night Foreman	..	..	..	⅓	F	5.00	⅓	F	5.00	⅓	F	5.00
Head amalgamators	2	10	3.50	1	10	4.00	1	10	4.00	1	10	4.00
Amalgamators	4	12	3.00	4	12	3.50	4	12	3.50	4	12	3.50
Crushermen	3	10	2.50	2	10	3.00	2	10	3.00	2	10	3.00
Oilers	2	12	2.50	2	12	3.00	2	12	3.00	2	12	3.00
Feeders	3	12	2.50	2	12	3.00	4	12	3.00	4	12	3.00
Laborers	1	10	2.00	2	10	2.50	4	10	2.50	3	10	2.50
Total	20½		59.00	19 1/18		64.32	23⅙		75.32	21⅔		70.07

A.—The Deadwood-Terra is on the opposite side of the hill from the Homestake and, although under that management, has its own foreman.

B and E.—One day foreman and one night watchman attend to the three mills, the Star, Highland, and Homestake.

C.—The Homestake and Star mills share the services of one mechanic.

D.—The Highland mill has its own mechanics.

A new mortar lying outside the Golden Star mill invited inspection, resulting in the following comments: The feed-hole is 4½ inches wide, and has vertical sides, a common but injudicious arrangement. The feed-hole should be smaller at the top than lower down, so that pieces of ore would drop down into the mortar freely, if they entered at all. (In the Father de Smet mortar, designed by Mr. Bowie, the top of the feed-hole is so narrowed.) The bottom of the feed-hole is too thin. This part of the mortar is the first to wear through. The lip is the next part to become worn out. Then holes begin to appear in the ends. The Homestake mortar lasts from four to five years. The back projection, designed to throw the splash to the front of the battery, is too near the shoe. The distance between the shoe and this portion of the mortar should at least be equal in size to that of the pieces of

ore which are permitted to enter. As it it less than this, pieces of ore often get wedged in and require dislodgement with a crowbar.

An incident worthy of notice was the trial, from November, 1888, to the middle of June, 1889, of a steam stamp, similar to those so successfully used at the Lake Superior copper mines. Its size was 11 by 26 inches, and it gave the best crushing results with 22-inch strokes and 95 of them per minute. The water consumption was $7\frac{1}{4}$ miner's inches per 24 hours, when crushing from 125 to 135 tons of ore, this being equal, therefore, to about 900 gallons per ton of ore. The steam pressure, when doing such work, was maintained at 85 pounds, but with 110 pounds pressure a maximum crushing capacity of 192 tons was attained.

Screens

No. 7 needle-slot screens, made of steel of No. 17 gauge, were employed. The use of a finer mesh entailed an enormous waste, owing to the pulp becoming banked up inside, always followed by the bursting of the screen. The screens were replaced every six days.

Tables

The amalgamating tables were 12 feet long by 4 feet wide, and the traps were 30 inches deep by 20 inches square inside. The tables had a fall of $1\frac{3}{4}$ inches per foot. Owing to the rapidity of the crushing no plates could be employed inside the mortar, and it was found that even when using screens of an identical kind the pulp issuing from the steam stamp was coarser than that discharged by the ordinary stamp mill, because the issue with the former was more forceful than with the latter. The crushing capacity of the steam stamp, as measured per cord of wood consumed for fuel, equaled the ordinary Homestake stamp, but the former crushed more coarsely. Moreover, the jar was such as to cause the amalgam on the tables to ball up, the mercury exuding and running away. This is a defect to be remedied by a slight change in the construction of the mill. In general it may be said that the steam stamp crushed too fast for either concomitant or subsequent successful amalgamation.

Before venturing on a criticism of the milling practice it will be necessary to indicate the conditions which have determined its character. The mines contain bodies of gold-bearing ore which, while low grade, are of such enormous

dimensions as to guarantee a large output for long periods of time, and justify the big scale on which operations are conducted. The ore itself is largely chloritic schist, unequally traversed by quartz. Certain portions of the country rock are quartzose and carry gold; they are therefore quarried above ground and stoped underground. There is no marked definition between what is valuable and therefore "ore," and what is valueless and therefore "country rock." The pay ore usually carries sulphides, of which iron pyrite, pyrrhotite, and arsenical pyrite are most noteworthy, and of which the last is more particularly the comrade of the gold.

The ore is broken without any attempt at sorting. Its low tenor and the mode of its occurrence alike render such a step impracticable. At one time the porphyry, flanking and overtopping the ore bodies, was sent to the mills. It is now dropped down to the lower workings and used as filling to sustain the timber work.

Extraction

In the 12 months ending June 1, 1894, the two Homestake mills treated 309,210 tons, and produced $1,390,610, equivalent to a yield of $4.49 per ton of ore. What the ore actually contained and what the tailings really carried away no one knows, but there is reason to believe that the loss in the tailings averages more than $1 and that the average extraction is not more than 75 per cent. At the Deadwood-Terra the output averages about 20,000 tons per month and the product of the mill has a value of about $32,000, making the yield per ton about $1.60. Even this material leaves a small margin of profit over all mining and milling expenses. The tailings are said to carry 30 to 45 cents per ton, from which, judging this to be the minimum, I would estimate the extraction to be slightly under 75 per cent.

The ore is indeed rushed through, but that is because it is so low in gold contents that slower treatment would cost too much per ton. It is reduced by methods both ancient and simple, but that is because the millstuff itself is of simple character, and neither invites nor warrants the use of complicated processes.

It is the old question of pushing technical perfection of treatment until it prejudices commercial success. Not that the two are antagonistic, except when one of them is carried

further than common sense suggests. Thus, there is no doubt but that if the mills were set to crush the ore at the more ordinary rate of 2 tons per stamp, the extraction would be increased, say 10 per cent, equivalent to a gain of 45 cents per ton, but then the cost of milling would be, if not doubled, at least largely augmented, equivalent to an increase, say, of 60 cents per ton. By crushing slower and thinning the pulp passing over the plates, amalgamation would be improved, but the increased extraction would be far more than offset by the added cost. Nor, it must be remembered, would this rapidity of treatment be accompanied by so small a loss, comparatively, were it not for the fact that the ore is of great simplicity, and yields up its gold readily to simple methods. In this respect it even surpasses the free-milling ores of the main belt of the foothills of the Sierra Nevada in California.

Such results, having in view the character of the ore and the rapidity with which it is rushed through the mills, is, I consider, very good work. It has been said by unfriendly critics that "haste and waste" best describes the methods of the Homestake Company. It has been urged that the methods are crude and extravagant in their seeming want of proper appliances to make the gold extraction complete. Such comment is largely due to a misconception of the objects aimed at. The milling practice from a purely technical standpoint is insufficient and inadequate, but from the commercial aspect of the matter it commends itself on the whole, barring certain details, as eminently successful.

The successful results are largely due to the pattern of the mortar. The Homestake mortar, in my opinion, is excellently designed to give the two results usually desired by the millman, namely, a large degree of amalgamation inside the battery, accompanied by a minimum interference with the rapidity of the crushing.

Before concluding it may be permissible to point out some respects wherein the milling appears open to criticism. The collection of the sulphides remaining in the pulp after amalgamation is, of course, totally inadequate, but it will be submitted that the present method is only experimental, an excuse which does not explain why so many years have been permitted to elapse without a proper settlement of the problem.

Two aprons deliver their pulp to one tail-plate of a size equal to a single apron. The gradient is the same in both cases. Therefore the lower plate is called upon to treat twice the quantity of pulp which goes over a single apron, and it is expected to do efficient work despite the well-understood fact that whatever gold escapes the apron must be finer, or otherwise more difficult to save, than that which has been arrested upon it. Instead of two aprons delivering to one tail-plate, one apron ought to pass its pulp on to two tail-plates, and by using additional water the pulp would be so spread over an increased amalgamating surface as to add largely to the chance of successful extraction. Such at least should be the idea instead of the reverse.

Table No. 5.

THE COST OF STAMP MILLING IN THE BLACK HILLS, SOUTH DAKOTA.

The Homestake Mill.	80 stamps. 1887–1888.	80 stamps. 1888–1889.	80 stamps. 1893–1894.
Tons treated	96,790	106,780	104,995
Labor	$0.2561	$0.2395	$0.2543
Supplies	0.0130	0.0045	0.0105
Water	0.1729	0.1562	0.1986
Wood	0.2766	0.2230	0.0597
Coal	....	....	0.1784
Machinery	0.0922	0.0893	0.1097
Oil	0.0009	0.0084	0.0034
Candles	0.0016	0.0014	....
Quicksilver	0.0103	0.0053	0.0083
Lumber	0.0070	0.0139	0.0167
Timber	....	......	0.0155
Total cost per ton of ore	$0.8406	$0.7415	$0.8551

The Golden Star Mill.	120 stamps. 1887–1888.	120 stamps. 1888–1889.	160 stamps. 1893–1894.
Tons treated	146,565	161,755	204,215
Labor	$0.2138	$0.1755	$0.1556
Supplies	0.0079	0.0044	0.0121
Water	0.1712	0.1622	0.2043
Wood	0.2739	0.1959	0.0346
Coal	....	....	0.1637
Machinery	0.1220	0.1088	0.1057
Oil	0.0084	0.0066	0.0021
Candles	0.0014	0.0014	....
Quicksilver	0.0252	0.0082	0.0071
Lumber	0.0054	0.0088	0.0160
Total cost per ton of ore	$0.8292	$0.6718	$0.7012

The wide tail-plates have only been in use three years. They were formerly 20 inches wide. At the Deadwood-Terra they are 16 inches wide and form a truly idiotic amalgamat-

ing device. "Sluices" they are aptly termed, since they are excellently devised for carrying off the pulp, the mercury, the gold, and everything else.

All the plates at the Homestake are of plain copper. Experience elsewhere commends the electro-plated copper, and especially in large establishments which can afford to do their own plating. The use of a 2-ounce or 4-ounce plated copper is especially to be recommended in the case of the tail-plates of the Homestake, since this would render it easier for the millman to keep them in order and would, I believe, increase their efficiency.

Rettie

Thus, in spite of the incompleteness due to a want of a progressive spirit in the management, the mills of the Homestake offer an excellent illustration of commercial success in the working of unusually large deposits of low-grade gold-bearing ores.

CHAPTER VII.

Early Australian Methods.

Clunes is famous in the history of the Colonies as the locality where on June 29, 1851, J. W. Esmond discovered the first gold in Victoria.* Its importance as a mining center has never been equal to that of the neighboring towns of Ballarat and Bendigo, but it is probable that no Australian mining district has done more useful work for the advancement of milling and mining. The history of its premier mine—the Port Phillip & Colonial—forms a large part of the early record of colonial "quartz reefing," and it is certain that in the history of milling in Australia that of the "Old Port Phillip" batteries forms the most important chapter.

Clunes commenced quartz mining in the Colonies. While Ballarat was astonishing the world with the rapidly succeeding discoveries of nuggets of wonderful size, and while Bendigo, still exploiting the rich alluvium, had not yet learned the value of the lodes whose white croppings were then only natural curiosities, Clunes was quietly laying the foundations of a great industry. It was fortunate that the difficult work of beginning was in the hands of the men who directed the affairs of the old Port Phillip. The Port Phillip & Colonial Gold Mining Company commenced operations in 1857, at a time when the opinion was generally held, owing to the rash generalizations of Sir Roderick Murchison, that the gold in quartz veins was confined to a comparatively shallow horizon. From 1857 to 1881, from surface to 1,400 feet, the mine produced 1,204,908 tons of quartz, yielding gold to the value of £1,946,989, or at the rate of 7 dwts. 14 grs. per ton. The dividends which were paid amounted to £481,455.†

*It was in August of the same year that gold was found at Bunninyong, starting the stampede to Ballarat, and in November that the Bendigo "rush" broke out.

† For these and other figures I am indebted to the courtesy of Mr. R. H. Bland, the manager and director of the company. I am also indebted to an interesting account of the mine by him, entitled, "The History of the Port Phillip & Colonial Gold Mining Company."

The portion of the mill which was first erected commenced crushing in May, 1857. At that date the treatment of gold quartz was a problem completely unsolved, and in the early years of its history the Port Phillip mill laid down the basis of Colonial milling practice. In 1861 assays proved the loss in the tailings to amount to 6 dwts. 1 gr. per ton. By numerous changes suggested by careful experiments, this loss was decreased until in 1870 it had been diminished to 17 grains. In 1862 the collection and treatment of the pyrites was commenced. In 1864 the plant was increased to 80 heads, and the first buddles were placed in position. In 1865 the first rock-breaker was introduced.*

As indicating the character of the work done at an early date, the quotation of the following figures is permissible:

Year.	Quartz crushed.	Amount of gold.			Average per ton.		Loss per ton.		Value.			Dividends.		
	Tons.	Ozs.	Dwts.	Grs.	Dwts.	Grs.	Dwts.	Grs.	£.	s.	d	£.	s.	d
1861	34,236	22,012	0	17	12	20	6	1	86,398	12	11	37,896	18	4
1862	40,360	22,988	1	19	11	11	4	9	91,336	5	8	28,081	4	5
1863	44,149	17,611	8	0	8	0	3	4	69,694	7	2	14,609	1	9
1864	54,418	20,596	10	12	7	14	1	23	81,865	19	7	18,583	7	11
1865	59,578	19,775	16	0	6	15	2	1	78,584	19	1	21,219	19	1
1866	58,287	26,828	8	0	9	5	2	8	106,458	6	9	43,683	19	9
1867	63,059	28,250	3	12	8	23	2	7	111,625	2	11	48,271	17	6
1868	69,810	25,517	19	0	7	9	1	22	102,836	11	6	32,812	14	7
1869	55,244	13,441	0	0	4	21	0	19	54,418	17	0	7,781	8	5
1870	65,229	18,613	11	0	5	17	0	17	75,199	12	4	19,889	19	0

The ore from the mine passes through two rock-breakers, preceded by sizing-bars ("grizzlies"), before entering the mill, which consists of several sections erected at different periods.

Number of heads.	Weight of heads or shoes.	Date of erection.
20	2½ cwts.	1857
24	2½ cwts.	1858 and 1859
12	2½ cwts.	1860
24	3¾ cwts.	1864

There are four stamps to each mortar box; four sections, three batteries each, on one side of the building, and three sections, two of three and one of two batteries, upon the other. The stamp heads or shoes are square. The mortars

* Previous to that time the ore was calcined to render it more readily broken and crushed. This practice has not yet altogether died a well-merited death in Victoria and New South Wales.

are provided with back and front discharge. The crushing capacity is at the rate of 2 tons 12 hundredweights for the 56 light stamps, and 3 tons 12 hundredweights for the heavier section. The speed is at the rate of 82 drops per minute, and the drop has a height of 8 inches. The issue or depth of discharge is maintained as far as possible at 4½ inches. The grating is of copper, pierced with 81 round holes per square inch. The pyrites concentrated (on Munday's Cornish buddles) has amounted to three-fourths per cent. of the ore crushed. Its average contents have been 4 ozs. 1 dwt. 14 grs. of gold per ton. The bullion is of 23.1.5 carats, or 965 fine. The retort percentage has averaged 38.

The business of the mill has always been carried on in a most systematic manner. The following tabulated statement of product is taken direct from the mill records for the four weeks ending May 21, 1873:

Where amalgam was produced.			Retorted.		Per cent. of total.
	Ozs.	Dwts.	Ozs.	Dwts.	
Beds or mortar boxes	1466	......	673	11	59.02
Boxes or wells	708	3	249	12	21.87
Blankets	408	2	121	12	10.66
Mills	383	......	96	7	8.45
Total	2965	5	1141	42	100.00

The other statistics were as follows: Number of stamps, 80; tons crushed, 5,023; hours worked, 518, or 21.58 days; average duty per stamp, 2.9 tons; yield per ton, 4 dwts. 10.12 grs.; loss in tailings per ton, 20.16 grs. total contents per ton, 5 dwts. 6.28 grs.

Of the total quantity crushed, 2,702 tons, or more than half, passed through the rock-breakers. Of the amalgam, that coming from the "beds" or mortar boxes retorted 46 per cent.; from the "boxes" or wells, 35 per cent.; from the blankets, 30 per cent.; from the Chilian mills, 25 per cent.

Of the total product obtained by direct amalgamation, more than half came from the mortar box, indicating the free-milling nature of the ore. No mercury was used in the mortar box. Of the total, 80 per cent. went no further than the wells immediately outside the mortar box.

The lower part of the sheet indicates the character of the extraction during that particular month. Of the average

contents of the ore—viz, 5 dwts. 6.28 grs.—only 20.16 grains were lost, giving a yield of 4 dwts. 10.12 grs. per ton, equal to 84 per cent. of the contents of the ore. At the present time the Port Phillip batteries are idle, but the milling practice which they inaugurated is to be seen reproduced in a modified form in the newer mills of the South Clunes United and the Dixon's North Clunes. The comparative table will illustrate the different features of the methods employed:

COMPARATIVE TABLE OF THREE CLUNES MILLS.

Mill.	Stamp.	Weight of stamp.	Drops per minute.	Height of drop.	Depth of discharge.	Capacity per stamp.	Capacity.	Grating.	Holes per square in.	Concentrates.	Contents of concentrates.		Bullion fineness.	Retort.	Loss of mercury per ton.	Wear of gratings.	Water per stamp per minute.
		Lbs.		Inches	Inches	Tons.	Tons.			Per ct.	Ozs.	Dwts.	Per 1000.	Per ct.	Grs.	Days.	Gals.
Port Philip .	56 24	728 896	82	8	4½	3	240	Copper plate.	81	¾	4	1	970	38	5¾	30	6
S.Cl'n United	60	896	80	8	4½	2½	150		100	⅝	3	5	968	42	5½	25	8
Dixon's N. Clunes . . .	30	896	80	8	7	3⅓	100		180	3	3	0	978	40	5½	*	10

The South Clunes United mill contains 60 stamps in six sections of two batteries of five each. The weight of the stamp is 8 hundredweights. The speed is at the rate of 80 drops per minute. The height of the drop varies from 6 to 8 inches. The depth of discharge or issue is kept fairly constant at 4½ inches. As the die wears down, sand is packed underneath, and when about 2 inches have been worn away, a second "false bottom" is placed under what remains of the die. This false bottom consists of a plain iron casting of a sufficient length to serve for two dies. One of half the length is used for the center stamp. The rate of crushing averages 2.4 long tons per 24 hours. In 12 months, working 16 hours per day and 6 days per week, there were crushed 28,820 tons. The "grating" or screen is of copper plate, 1½ pounds of copper per square foot. It is perforated with 100 holes per square inch. The average wear at present is about a month, or, say, 25 working days, working full time. Iron-punched

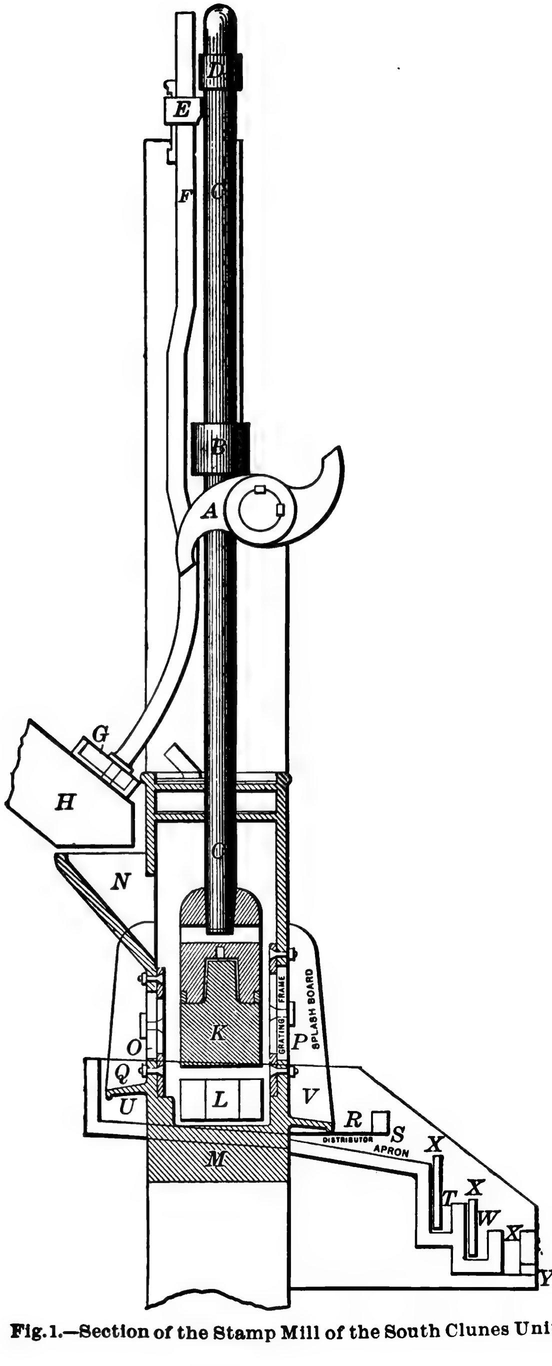
* Information not obtained.

gratings were found not to last for a week. The percentage of concentrates is usually 1 per cent., having increased slightly as depth has been attained in the mine. In the upper workings it was three-fourths per cent. The concentrates usually carry 3 ounces of gold per ton. Just now, however, the ore is poor and is yielding at the rate of 178 tons 19 cwts. 3 grs. of pyrites, worth £560 12s. 18d., from the crushing of 28,820 tons of ore. The bullion is 23¼ carats, or 969 thousandths fine. The percentage of gold in the amalgam varies from 36 to 45. The water consumed is at the rate of 8 gallons per stamp head per minute. The loss of mercury is unusually small and amounts to 5½ grains per ton of ore crushed.

We will now follow the ore through the different stages of its treatment. The millstuff is trammed from the mine and discharged into the ore-bins. There are no rock-breakers, but self-feeders of a simple pattern pass the ore on into the mortar boxes, which are of peculiar design and are provided with both back and front discharge. No mercury is used in the mortar box. The pulp issuing from the battery passes through wells and then over blankets. The blanket washings are treated in revolving barrels with the addition of mercury. From the blankets the tailings go to Cornish buddles, which are further supplemented by tyes placed outside the mill.

Such, briefly, is the mode of treatment. There are many interesting details to be noted. The mine is distant one-third of a mile from the mill, and the tramming and breaking of the ore are done under contract for 8 pence per ton. The feeding of the ore is regulated by a simple contrivance which is shown in the accompanying Fig. 1.* *H* indicates the lower end of the shoot leading from the ore-bin; to it is attached the lower end *G* of the iron rod *F* which, at its top end, has a disc *E*. This disc *E* is keyed to the rod and projects under the false or extra tappet *D* upon the stem of the center stamp of a battery of five heads. When the feeding is low the stamp falls further than usual, and in so doing causes *D* to strike *E*, which communicates the shock to the ore-chute *H*, and so causes the ore to fall forward into the feeding hole *N* of the battery.

*This drawing I owe to Mr. Thomas Hewitson, the manager. I am also under obligations to him for information which he gave me.



The pulp passes over 12 feet of blankets, then through buddles and afterward over 25 feet of tailings, blankets and tyes.

Fig. 1.—Section of the Stamp Mill of the South Clunes United Co., Clunes, Victoria

The disc or tappet is kept in place by keys. The order in which the stamps drop is 3, 5, 2, 4, 1. The shoes are of cast iron, 10 inches in diameter and 10 inches high. The dies or false bottoms are hexagonal in section; they are made of wrought iron and have a diameter of 10 inches and a depth of 6 inches. New shoes weigh 196 pounds; new dies 140 pounds. A shoe will crush 90 tons, and a die 420 tons, before it is worn out. Cast-iron shoes cost 12s. 6d. per hundredweight, and wrought-iron dies 11s. 6d. per hundredweight, delivered at the mill.

The mortar box is provided with a double discharge, behind as well as in front. In both cases the distance from the bottom of the screen to the top of the die is kept at about 4½ inches. The screens or gratings are similar in coarseness.

The accompanying drawing illustrates the mortar and its accessory appliances. The front grating frame *P* is 5 feet long by 13 inches wide, while that behind, *O*, is 5 feet by 12 inches. Both are placed in a vertical position and are covered by a "splash board," which slopes forward. The pulp issuing at the back passes over the lip *Q* and is conducted by the launder *U* to the front of the battery, where it unites with that which is being discharged in front.

The pulp discharged through the front grating passes over the lip *V*, and, uniting with that from the back of the mortar, goes over a perforated iron plate *R*, called the distributor, by passing over which it is evenly spread over the width of wells and blankets which follow. This plate is 1 foot deep and 3-16 inch thick, perforated with holes 5-16 inch in diameter, drilled at the four corners of a square inch. Then follows the "apron" *S*, a plain wooden table 20 inches deep and 2 inches thick, which further aids the even distribution of the pulp. Two wells, *T* and *W*, succeed. They are covered and guarded from theft by a wooden rack kept under padlock. The first well, which succeeds the apron, has a drop of 10 inches and a depth of 4 inches. It holds 50 pounds of mercury. It will be noted that the upright board *X* compels the pulp to pass through the body of quicksilver in the trough before escaping, and so insures a contact with the quicksilver. The second well, *W*, which follows immediately after, has a drop of 8 inches, a depth of 4 inches, and also contains 50

pounds of mercury. These wells, including the lip, are of cast iron; they have a curved inside contour, and are sunk into the wood of the frame which holds them. It has been found that iron wells are preferable to wood, since the iron has a beneficial effect upon the mercury, tending to keep it "lively," or chemically active, much as in pan amalgamation. The wells have an inside diameter of 3 inches, and are placed so as to have a slight slope to one end, where a tap-hole renders easy the removal of the mercury at cleaning-up time.

The pulp now goes over the blanket tables *Y*. The blankets are spread upon tables having a width which takes in both of the two 5-head batteries forming a section. The total width is subdivided into seven partitions, each 18 inches across and 12 feet long. The grade is three-fourths inch per foot. Then follow five improved circular Cornish buddles (Munday's patent), and finally the tailings pass over the "tyes," which are outside the building. These last have a length of 20 feet and a fall of 1 inch per foot.

The gold saving is done by the mortar box itself, by the mercury troughs or wells, and indirectly by the blankets, buddles, and tyes. In the mortar box or coffer no mercury is employed. The use of copper gratings would in itself prevent it, but the very free character of the gold does not necessitate its use at this stage of the treatment. The mortar box is a roomy one, and gives the gold an opportunity to separate itself from the pulp by the action of gravity alone. The dimensions are: Interior length of mortar, 58 inches; interior width, 16 inches; distance between dies, 1 inch; distance from end die to side of mortar, 2 inches; distance from die to back of mortar, 4 inches; distance from screen to die, 3 inches; distance from center to center of dies, 11 inches. The mortar boxes are approximately rectangular in horizontal section.

In cleaning up, the grating frames are taken down and the material found inside, between, and around the dies is shoveled into buckets and then passed over a common strong wire sieve or "riddle" 2 feet in diameter and of No. 4 mesh. One of these lasts for 12 months. The roughs from this operation are returned to the mortar box, and are used to reset the dies before starting again. At each fortnightly clean-up

from 1½ to 2 small bucketfuls are obtained. The fine is sifted into a blanket trough and then introduced into an amalgamating barrel.

There are five such barrels in the mill. The accompanying sketch, Fig. 2, will illustrate the arrangement. *A* is the barrel itself, having a capacity of 54 gallons. It makes 16 revolutions per minute, and is worked from 8 to 12 hours, 10 hours being the usual period. The water used is not warm. Seventy-five pounds (a bottle) of mercury are added to each charge, together with a bucketful of wood ashes.

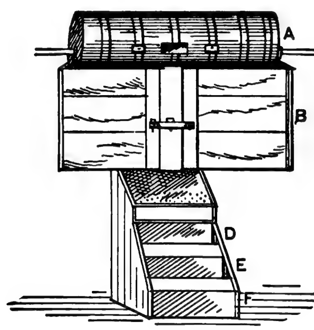


Fig. 2.

When the amalgamation is completed the contents of the barrel are emptied into the wooden tank or box *B*, to be discharged first over a perforated iron plate *C*, and then to pass on to the three drop wells *D*, *E*, and *F*, having a drop of 12, 9, and 6 inches respectively. Nearly all the amalgam is caught in the top well, a small proportion only reaches the second, while the third is merely a safeguard and is only cleaned up occasionally. This disposes of the treatment of the residues found in the mortar box.

We next come to the wells, which are cleaned up once per week. The mercury is squeezed through canvas cloth and the excess of quicksilver separated from the amalgam. The skimmings taken from time to time from off the surface of the mercury in the wells, and consisting largely of heavy pyrites, are treated in Berdans,* of which there are three, each 3 feet in diameter. The blankets are washed in tubs, the first row

*Small pans placed at an inclination in which the grinding is done by a ball which remains at the lower end and turns round as the pan revolves.

every hour, the second every alternate hour, and the third every third hour. With rich ore the washing is done more frequently. The blanketings or residues from the washing of the blankets are treated in the amalgamating barrels in much the same manner as described in the case of the mortar-box residues. The material collected by the "tyes," straight troughs in which heavy pyrites, escaping amalgam, etc., collect by the action of gravity alone, is also treated in a barrel. The tailings from all the barrels go to certain of the buddles. The pyrites obtained from concentration on the buddles is roasted in a reverberatory, and then ground in a Chilian mill, with the addition of mercury, which collects the gold in the form of amalgam.

The total yield of the mill is variously distributed. In one month 2,973 tons were crushed, yielding 981 ozs. 19 dwts. 12 grs. of gold. Of this total the different parts of the mill contributed as follows:

	Amalgam.		Bar gold.		Retort per cent.
	Ozs.	Dwts.	Ozs.	Dwts.	Per cent.
Mortars (beds)	955	5	840	19	36 to 48
Wells (boxes)	644	19			
Blankets (by the barrels)	364	15			
Skimmings (by the Berdans)	167	14	53	2	32
Tailings (by tyes and barrels)	24	10	7	5	30
Concentrates (pyrites) 17 tons	310	4	80	13	26

It will thus be seen that of the total amalgam saved in the mill itself (neglecting concentrates and tailings) the percentage is thus distributed: Mortar boxes, 44.8 per cent.; wells, 30.2 per cent.; blankets, 17.1 per cent.; skimmings, 7.9 per cent. It must be remembered that in the case of the yield from the mortar box the gold is actually saved as such, and it is only in the after-treatment that mercury is used to collect it.

The loss of mercury for the past seven years has averaged 5½ grains per ton of ore crushed. Occasionally the loss has risen up to 1½ ounces per ton of ore, this being due to copper which formed copper amalgam. Such copper amalgam floats upon the surface of a bath of mercury and is readily carried away with the tailings. This was not due to the abrasion of the copper gratings, as might be imagined, but was owing to

the presence in the ore of particles of native copper. At one time as much as 80 ounces of copper were collected in one month from the skimmings of the wells. The wearing of the copper of the gratings does no appreciable harm.

The total consumption of mercury, including the treatment of pyrites by Chilian mills, as well as in the mill proper, during 11 years—from July 1, 1881, to June 30, 1892—has been 3,302 pounds. During that time 309,400 tons of ore were treated, so that the loss amounts to about 3 pennyweights per ton of ore. The loss at the Port Phillip & Colonial mill during seven years was, including treatment of pyrites, about 5½ pennyweights. A good deal of this loss was, however, subsequently recovered.

The gratings or screens used invite examination. Mr. Hewitson, the manager, informed me that up to the year 1879 the gratings used were imported from England. They were made of copper plate, one-sixteenth of an inch thick, and drilled with 81 holes per square inch. When in full work the imported article lasted 12 months, or during the passage through the grating of 2,200 long tons of ore.* At the Port Phillip, owing to the smaller area of discharge, the life of a grating reached one and a half years.

The protective tariff caused the imported grating to become too expensive, and the domestic article took it place. This wore for less than half the time of the imported one. As compared to the ordinary punched iron it lasted, however, six times as long. The experience with the present lighter type of copper grating has been very good. During the past seven years 258 gratings have been used up; their cost was £197 6s., and during that period 181,792 tons were crushed, or at the rate of 355 tons (397 short tons) during the life of a grating. It was found that the ordinary round-punched Russia iron lasted scarce a week as against a month for this type of copper grating.

Baize is used for the blanket strakes. For one year the cost under this head amounted to £47 9s. 2d. During the same period the wages at the mill amounted to £1,306 4s. 9d. for the treatment of 28,820 tons of ore, or 10½d. (21 cents) per ton. The total cost of milling, including supplies, wear and

* That is, the front and back gratings together are passed through 4,400 tons.

tear, treatment of pyrites, etc., amounted to 2s. 3d. (54 cents) per ton of ore.

The Dixon's North Clunes mill is very similar to that just described. A few minor differences may be noted. The front grating is of copper, 180 holes per square inch, while the back grating is of brass wire, 230 to 240 holes per square inch. In this mill there are six of Munday's patent buddles with iron scrapers, two to each 10 stamps. At the South Clunes United there are only five to the 60 stamps; not enough. Assays are made daily, and the tailings are found to be very clean. The pyrites is washed and then treated in a Chilian mill. Cost per ton, £1 16s. 11d. The roasting of 85 tons 1 hundredweight cost £89 6s. 7d.; grinding, £67 15s. 11d., or a total cost of £157 2s. 6d. The furnace is a reverberatory, 40 feet by 5 feet.

Returning to the examination of the figures given in the comparative table it will be noted that both the newer mills follow very closely upon the lines of the old Port Phillip. The weight of the stamps—8 hundredweights—is that which is most usual in the Colonies. Of the three mills the South Clunes United is the only one without a rock-breaker, and the result is to be seen in the smaller crushing power. The Dixon's North Clunes uses the finest grating, but in so far as this affects the rate of crushing it is fully compensated for by a less depth of discharge. The weight of the drop is practically the same in the three mills. Although the gold in the Dixon's is probably coarser than that in the ore treated at the South Clunes, the retort percentage is not quite so high because the finer size of grating used at the Dixon's produces finer crushing, and causes the amalgam to be somewhat more contaminated by pyrites. The large quantity of water consumed at all these mills is necessitated by the double discharge and the use of very wide blanket tables. The consumption of mercury is extremely low. The chief source of loss in a mill, that due to the flouring of the mercury by its violent agitation with the particles of the pulp when under the stamps, is here avoided, since none is put into the mortar box; 5½ grains per ton is probably the smallest loss of mercury in a gold mill of which we have record.*

* The other record, that for extreme waste, is held by the Caledonia mill, at the Thames, N. Z., where it is stated that one ton of mercury was used up in two weeks by a mill of 20 heads only.

Before venturing to criticise the methods of gold extraction employed at the mills of this district, it will be necessary to consider the character of the ores. These are broken from veins of quartz traversing slate and sandstone beds. When sent to the mill the quartz is accompanied by a comparatively small admixture of country rock. The quartz is white, often honeycombed, and sometimes sugary. The gold which it carries is coarse, of very high caratage, often visible to the naked eye, and arranged for the most part along the faces of small fractures and seams traversing the quartz. A blow tends to readily detach the gold from the quartz. Occasionally the quantity of "mullock" or waste rock increases considerably, and the gold is accompanied by pyrites, chiefly arsenical iron sulphides, or occurs in a matrix composed of quartz and slate intermixed.

Such, briefly, is the nature of the ore. The accompanying record, covering 14 years, will give a good idea of the completeness of the extraction and the proportion of the value saved by the several contrivances which together make up the treatment. It is taken from the millbook of the Port Phillip & Colonial Company.

THE PERCENTAGE OF GOLD OBTAINED.

	Beds.*	Boxes.	Blankets.	Mills.	Blankets and mills.	Yield per ton.	
						Dwts.	Grs.
1865	63.60	22.09	10.55	3.76	14.31	7	13¾
1866	65.60	22.63	8.73	4.04	12.77	6	15
1867	65.44	22.50	8.48	3.58	12.06	9	5
1868	63.22	24.03	8.11	4.64	12.75	8	23
1869	61.33	24.77	8.02	5.88	13.90	7	8
1870	60.15	26.69	2.74	10.42	13.16	4	20¾
1871	62.59	25.39	....	12.02	12.02	5	17
1872	64.48	21.60	1.06	12.86	13.92	4	17¾
1873	59.20	20.67	10.35	9.78	20.13	8	23½
1874	56.14	22.54	13.24	8.48	21.32	4	1½
1875	54.81	25.14	11.22	8.83	20.05	4	23¼
1876	58.17	21.24	11.12	9.47	20.59	5	4
1877	52.84	21.56	15.40	10.20	25.60	6	20¼
1878	52.84	17.12	17.11	12.93	30.04	7	20¾
1879	57.99	10.50	12.84	18.67	31.51	8	19¾

It will be noted that in 1870 the use of blankets was discontinued and during 1873 it was again resumed. During the interval, it will be remarked, the yield from the Chilian mills, which treated the concentrated pyrites, increased con-

* The terms "beds," "boxes," "mills," correspond to "mortar boxes," "mills," "Chilian mills," respectively.

siderably. Looking down the first two columns it is seen that while the proportion of the total yield coming from the mortar boxes (or "beds") and wells (or "boxes") amounted to 87.03 per cent from 1865 to 1868, it declined to an average of 73.08 per cent. for the last four years. In 1879 it was only 68.49 per cent. In the meantime the yield from the blanketings and concentrates (as shown by the product of the Chilian mills) increased correspondingly. The first two columns represent that part of the gold contents which is essentially "free," while the third and fourth columns represent the remaining portion which is rebellious or "refractory."

The explanation of the figures above referred to lies in the fact that the mine workings having become deeper, the ore, by the steady increase of the percentage of pyrites contained in it, had become less "free milling." On referring to the returns obtained from the pyrites this reasoning is confirmed, for while in 1866 the yield of concentrates amounted to 268 tons, averaging 2 ozs. 19 dwts. 4 grs. from the crushing of 59,578 tons, in 1879 the pyrites amounted to 421 tons, averaging 4 ozs. 15 dwts. 20 grs. resulting from the treatment of 56,766 tons.

To consider the methods in use: It will be allowed that in milling the use of costly chemicals is to be carefully avoided. Mercury is the one chemical most generally used. Since a large (55 per cent. to 65 per cent.) percentage of the gold in the ores treated at the Clunes mills can be arrested in the mortar boxes by the action of gravity alone, the practice of the district is altogether correct in so far as concerns the non-employment of mercury in the battery. When under the stamps mercury is always subject to "flouring"—that is, breaking of it into minute globules, which, collecting impurities, become covered with a film, causing them to refuse to coalesce and so to be carried away with the tailings. Together with the direct loss of mercury there must always be also an indirect loss of gold, particles of which have entered into amalgamation with the escaping globules of mercury.

The absence of copper or other amalgamating plates is remarkable. This also, keeping in view the character of the ore, is correct. Wells are excellent gold-saving appliances

for ore of this type, in which the precious metal is both free and coarse. They require less attention, their first cost is less than that of amalgamating plates, and they are less affected by the occasional presence in the ore of minerals which are injurious to amalgamation.

Blankets, when they are intelligently used, are also among the best of the simple contrivances known to the millman. Instead of having the bad arrangement, seen in so many mills, of giving them a width much less than that of the amalgamating tables or mortar boxes, which precede them, the blanket tables here have the full, uninterrupted width of two batteries. At the South Clunes United there is a clear blanket space of 10½ feet.

Ordinarily the slope of the blanket strakes or tables would be from 1¼ to 1½ inches per foot, but at Clunes, owing to the employment of a larger quantity of water,* one is able to work them with an inclination of only three-fourths inch per foot. This is in itself an important factor, though apt to be overlooked.

The after-treatment in the barrels may appear crude, but practice has shown that it is very effective. The bad custom, observable in some California mills, of putting pieces of iron into the barrel (with the idea of mixing up the pulp and grinding it) does not prevail at Clunes. It is a device which serves mainly to cause excessive loss of mercury which, quite as much as the pulp, becomes ground and so "floured."

The double discharge (front and back) presents no striking features. It is successful in slightly increasing the crushing capacity of the mill, though it will be noted that it also requires the use of a much increased supply of water.

The depth of discharge is a factor in milling the importance of which is almost invariably overlooked. The mills of this district are not guilty of the vicious practice of allowing a wide difference between the minimum and maximum depth of discharge, caused by the wearing down of the dies. An endeavor is made to keep the depth of discharge fairly constant, first by regulating the packing under the dies, and then by the placing below them (as they wear down) of a false bottom.

* Due, as pointed out, to the use of the double discharge.

Though the self-feeders used are not automatically perfect they do their work well, and, it is needlesss to add, are a great improvement upon the bad, irregular hand-feeding which prevails in the majority of colonial mills.

The concentrating machinery may with reason be considered somewhat out of date, but the modified Cornish buddles in use are doing most excellent work, and it is doubtful whether they would be replaced to advantage by the more costly Frue vanner.

Speaking generally, the treatment which the ore undergoes is remarkable, most of all on account of its simplicity, but so is the ore; and in this way the practice of the district carries out the first postulate of intelligent milling, viz, that the treatment should be varied according to the character of the ore to be treated.

After a careful examination of the ore mined at Clunes, and of the milling to which it is subject, it is not possible but to speak in words of commendation. To a millman Clunes is almost solitary among the gold-mining districts of the Colonies in being a quartz-milling center which does not leave a feeling of dissatisfaction and an impression of disappointment. The old Port Phillip is still working, but as a great mining and milling establishment it is a thing of the past. That past has, however, been a glorious one, not so much by reason of the dividends which it has paid, but because of the successful experimental work which it carried on for so many years at a time when such work was especially needed. The immense good it has done as an educational center and a training ground for millmen is not known save to those acquainted with the work which was done at Clunes from 1857 to 1880. You may visit mills in the most distant parts of Australia and almost without exception, wherever you find good, intelligent milling (and that does not happen too often to be monotonous) you will also learn that that knowledge and experience were obtained at the small Victorian town of whose record we are speaking.

The Port Phillip was the first to introduce the system of taking daily assays as a check upon the work done in the mill. In this respect Clunes is still, unfortunately, a striking exception.

In another department this mill was almost a solitary pioneer. The rock-breaker was introduced by the Port Phillip in 1865. Can it be believed that in these days of improved milling machinery, when the rock-breaker is accepted as an absolutely necessary portion of a complete mill equipment, that in the great gold mining colony of Victoria there are only 12 rock-breakers? Of this number three are accounted for by Clunes, two belonging to the Port Phillip, and one to the Dixon's North Clunes.

In closing this short account of the milling practice of a district but little known beyond the colonies, it will be pardoned if I express the opinion that the work done at the Port Phillip & Colonial Company's mill has been of more wide-reaching usefulness and more permanent benefit to the mining industry of Australia and New Zealand than that of any other company which has gone into operation since the days of the discovery of gold. I wish to record my conviction of the debt which quartz milling in the Colonies owes to the manager, Mr. R. H. Bland, of the Port Phillip, who started the operations in 1856, conducted the numerous and valuable experiments which did so much to establish the correct basis of milling practice, and to-day still assists the industry by his sterling good sense.

CHAPTER VIII.

More Modern Australian Methods.

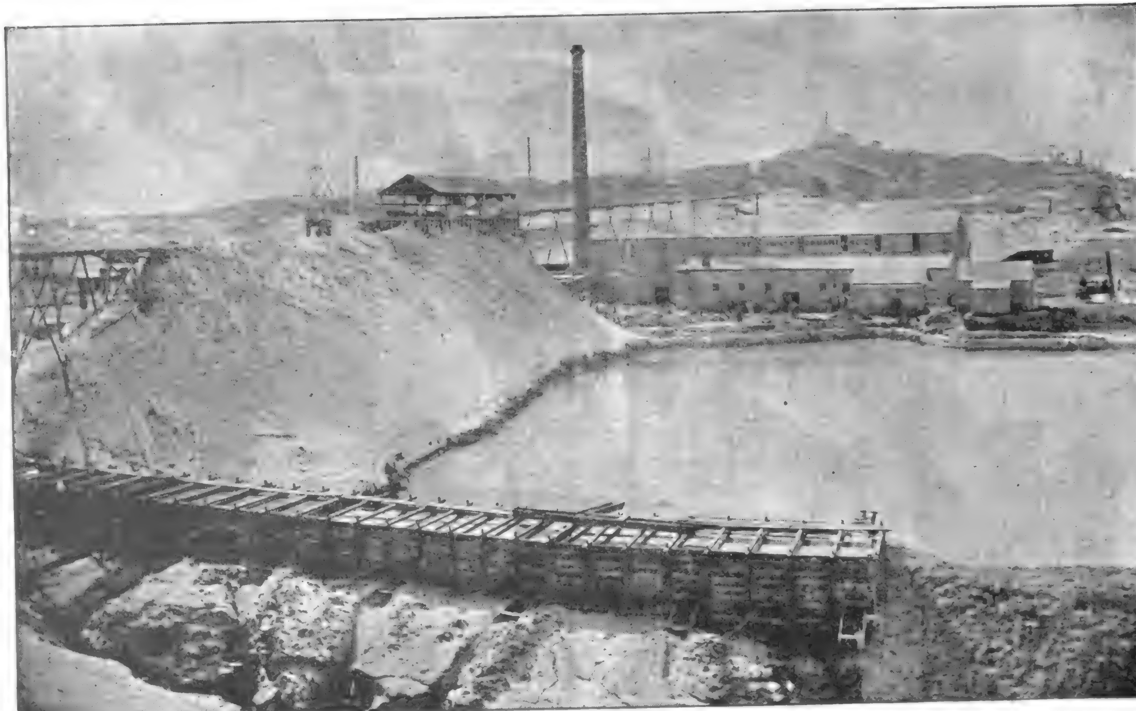
When gold was first found at Golden Point in August, 1851, the history of Ballarat began. It marked the commencement of a record more brilliant than that of any other of the great discoveries of that golden year. To-day Ballarat is the largest gold-producing mining district in Victoria, for, unlike many of the rich diggings of the early days, it has not yet outlived its first reputation. The working of the rich alluvium commenced the development of the mineral resources of Victoria, and laid the basis of the commercial wealth of Melbourne. That alluvium, however, has been largely exhausted and at the present time more than half the gold product of Ballarat is derived from the quartz lodes. It is a remarkable fact in the history of mining that mines which had produced largely from the alluvium became no less profitable as quartz mines, for in the bedrock of the deep leads were found the croppings of the quartz veins whose erosion in a bygone period had enriched those deep leads.*

For the year 1891† the output of the Ballarat district amounted to 202,740 ozs. 1 dwt. 12 grs., of which 74,768 ozs. 13 dwts. 3 grs. were alluvial and 127,971 ozs. 8 dwts. 9 grs. came from the quartz. Dividends amounting to £222,839 15s. 0d. were paid during the twelve months. The average yield of the quartz was at the rate of 8 dwts. 1 gr. per ton, while the pyrites (concentrates) contained 2 ozs. 3 dwts. 2 grs. per ton. The price of the gold varied from £3 17s. 6d. to £4 3s. 0d. per ounce.‡ At the present time there are at work in the district

* At the Band and Albion 519,551 ounces, worth £2,078,235, were obtained from the alluvium up to 1879, when the value of the quartz reef in the bedrock was recognized. Quartz succeeded alluvial mining, and gold of the value of £607,380 was obtained up to June, 1888. Total gold obtained, £2,685,615; dividends, £1,415,533.

† For 1894 the total output from Ballarat was 194,820 ozs. 5 dwts. 12 grs., of which 76,269 ozs. 3 dwts. 3 grs. were alluvial, and 118,551 ozs. 2 dwts. 9 grs. came from the quartz. The dividends paid amounted to £151,269 0s. 5d.

‡ For these figures the writer is indebted to the *Annual Report of the Secretary for Mines*.



Crushing Mill at Ballarat, Australia.

1,246 stampheads, 21 buddles, 4 stone-breakers, 28 concentrating tables, 2 Wheeler pans, 11 Berdans, 7 Chilian mills, and 6 Arastras. The average price paid for crushing quartz is 5 shillings per ton. A 5-head battery can be hired at the rate of 2½ shillings per hour.

The comparative table which follows will give figures illustrating the chief features of the methods of work employed at four of the principal mills:

COMPARATIVE TABLE.

Name of the mill.	Number of stamps.	Weight of each stamp.	No. of drops per min.	Height of drop.	Average depth of discharge.	Crushing capacity per stamp.	Crushing capacity of mill.	Description of grating.	Fineness of grating holes per square in.	Percentage of concentrates.	Contents of concentrates per ton.	Fineness of bullion.	Retort percentage.	Wear of gratings.	Consumption of mercury per ton of ore.	Consumption of water per stamp per min.
		Lbs.		Inches.	Inches.	Tons.*	Tons.			Per ct.	Dwt.	Per 1000.	Per ct.	Days.	Dwts.†	Gals.
Star of the East.	60	1008	73	8¼	3	2	120	Round-punched Russia iron.	200	3½	69	970	46	10	5.7	7½
Ditto old Mill.	20	784	75	8¼	3	1.5	30		150	3½	69	970	46	12	5.7	7½
Britannia United	40	1050	60	8	1½	2.1	84		120	1	27	978	50	14	2.6	5
New Normanby.	20	784	60	7	4½	2	40		120	no	ne.	965	70	12	5.6	5
North Cornish.	50	784	72	8	1½	1.8	90		160	2½	113	935	33	6	4.9	2½

The Star of the East at Sebastopol‡ was for many years the most productive gold-quartz mine in Victoria.§ The ore is treated at the two mills, one of which contains 60 stamps and the other 20. The larger plant is only two years old, while the smaller dates seven years back.

Going to the new mill first it is found that it consists of 60 stamps in two 30-head sections. Each stamp weighs slightly over 1000 pounds and drops 73 times per minute. The height of the drop varies from 8 to 8½ inches. The center stamp of a battery of 5 heads drops one-half inch less than the other four. This is said to produce a better splash of the pulp against the grating or screen. The order of the drop is 5, 3, 4, 2, 1. The discs or tappets are of screw pattern. The depth

* Long tons, 2,240 pounds.

† A flask of mercury in the colonies contains 75 pounds avoirdupois.

‡ Ballarat was born during the time of the Crimean War, and the names of former battlefields adorn every street corner.

§ During 1891 this mine produced 34,092 ounces gold and paid £79,200 in dividends.

of discharge or issue—the distance from the bottom of the grating to the top of the false bottom or die—is 2 inches when starting with new dies. Sand is packed tightly underneath. As the dies wear down a maximum depth of discharge of 4 inches is attained. When the gold in the ore is found to be unusually fine the dies are allowed to wear down still further so as to obtain as deep an issue as possible. The capacity of the mill is at the rate of 1,450 long tons per fortnight of 12 working days. The grating or screen is of round-punched Russia iron having 200 holes per square inch. Such gratings last for 12 days. On rare occasions, when ore containing gold in an unusually finely divided condition is encountered in the mine, gratings having 270 holes per square inch are substituted and their time of wear is only 3 to 5 days. As a rule the gold is fairly coarse, though there is a marked difference in this respect between the product of the two lodes being worked in the mine. The percentage of concentrates obtained is 3½. They contain from 3 ozs. 5 dwts. to 3 ozs. 13 dwts. per ton, and are sent for treatment to the chlorination works at Bendigo.*

The bullion is very high grade, averaging 970 fine. The percentage of bullion obtained in retorting is found to vary with the ore broken from the two lodes. The amalgam from the No. 2 shaft retorts 45 per cent.; from the No. 1, 48 per cent. The grade of the ore is in accordance with the retort yield, viz, 13 and 17 dwts. per ton, respectively. This is in harmony with the usual experience that rich ore, because the gold is also usually more coarse, yields higher grade amalgam.

The amount of water used is at the rate of 7½ gallons per stamp per minute, not including the boiler supply. In one month 16,588,800 gallons are consumed. The loss of mercury amounts to one bottle, or 75 pounds avoirdupois, per month. This includes that consumed at the old mill and is at the rate of 5.7 dwts. troy per ton of ore crushed.

In this mill the gold saving is done in the mortar box, by copper plates outside, by wells or mercury traps, and indirectly by the blanket strakes and shaking tables. The mortar box is made an amalgamator by the introduction

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* Since the time when the writer was at Ballarat a new chlorination plant has been erected in the town itself.

every two hours of a teaspoonful (4 ounces) of mercury. There are no amalgamating plates inside. The amalgamating tables outside are covered with sheets of plain copper. They have a grade of seven-eighths inch per foot. At their lower end there are two drop-wells and one shallow well. These catch but very little gold; indeed, when the copper plates above them are in good order they simply serve to arrest escaping mercury. Next come the blankets. The blanketings—the residues from the regular washing of the blankets—were formerly treated in an amalgamating barrel, but now they are stacked, lime is added and they are allowed to stand for two days, after which they are fed into the battery in company with the usual ore supply. Below the blanket strakes are 8 ordinary shaking tables of inferior pattern. They do not discharge the concentrates automatically. The pulp which escapes from these passes over "tyes" or straight sluices. Three Berdans are used for grinding the skimmings from the wells.

The old mill contains 20 heads, weighing 785 pounds each. It has a crushing capacity of 350 long tons per fortnight of 12 working days. The arrangement of the different parts is very similar to that of the new mill. The copper amalgamating tables incline at three-fourths inch per foot. They are preceded by two, and followed by three, wells. Then come two strips of blanket having a total length of 8 feet and a gradient of 1¼ inches per foot. These are succeeded by four shaking tables, one to each battery. Two Berdans are used in the treatment of skimmings. A ball is first used and then a stationary drag, the amalgamation being carried on during both stages. It would be better to do the grinding of the material first with the ball and then add the mercury, and do the amalgamation during the supplementary grinding done by the drag. The drag being stationary would not work upon the quicksilver; the former is placed at the side of the pan and the latter settles at the lower end. Less mercury would then be lost by flouring.

The two mills compared.—The working of an old plant side by side with a new one treating the same ore naturally invites a comparison, which in this instance is prejudicial to the newer, larger, and more costly mill. The millman acknowl-

edges that the older mill is doing the better work. In this he is, I believe, correct. The main distinction between the two consists in the fact that in the 60-stamp mill the copper plates do that part of the gold saving which in the 20-stamp mill is accomplished by wells. In both cases the bulk of the gold does not go further than the mortar box itself, but is arrested by the action of gravity aided by the free mercury introduced by the feeder. Of that which escapes from the battery the plates get the larger portion in the new mill, but in the old one it is obtained by the two wells which precede the copper plates. Which is the better arrangement? The plates have a greater first cost and they require far more attention than the wells. It is only in comparatively exceptional cases, where the ore does not contain a large percentage of sulphurets and where the gold is comparatively "free," that wells can be satisfactorily used instead of plates, but where, as in this instance, they are found to accomplish the work of arresting the gold they are for the above-stated reasons much to be preferred.

In both mills the feeding is done, and done badly, by hand. Four laborers (three young fellows and one man) are employed per 8-hour shift in keeping the 60 heads supplied.

It is the custom to add a bucketful of lime to each 10 heads every two hours, since this is found to prevent the formation upon the amalgamating tables of a black scum due to the presence in the ore of sulphated pyrite.

By way of further criticism it is not too much to say that it is but a sorry result that with such a large and productive mine, situated in a very enterprising mining district, the new mill should be so far behind the ideal. There is absolutely no excuse for the want of a rock-breaker and the absence of proper feeding machines. The cost of such an installation cannot be pleaded by one of the wealthiest mining companies of Australia. Fault must also be found with the concentrating machinery, which is altogether inadequate to the requirements of the mill. An increase is wanted in the number of shaking tables, but in making any addition it would be well to secure percussion tables of proper design, discharging the concentrates automatically.

At the Britannia United on Bakery Hill* there are 60 stamps. The most important figures indicative of the method of milling are given in the comparative table. The ore is somewhat more free milling than that of the Star of the East, as is shown by the lower (1 per cent.) percentage of concentrates, the greater fineness of the gold, and the increased retort yield.† The bullion is of an unusually high caratage, being worth £4 3s. 0d. per ounce‡ or 978 fine. The coarseness of the gold in the ore is shown by the retort percentage, which, while it sometimes reaches 65, averages 50. The gold saving is effected by methods similar to those described at the 60-stamp mill of the Star of the East company. One ounce of mercury is added to the mortar box per ounce of gold in the ore. Immediately outside the battery there is a well 1½ inches deep and 3 inches wide, containing 10 pounds of mercury. The copper plates have a grade of 1 inch per foot. The blanket strakes are 16 feet long, in three longitudinal divisions each 17 inches wide. They have a slope of 1¼ inches per foot. Quicklime is added to the battery at the rate of 5 pounds per each 5 heads per 24 hours. The water used in the batteries is warm and is made so by conducting the condenser water of the engine into the tank which supplies the mill.

Lime addition

Two points open to discussion are here suggested, viz, the use of warm water and the addition of lime. The object of heating the battery water in such a warm climate as that of Ballarat does not appear very evident. The use of condenser water in any mill is decidedly objectionable. To consider these two propositions, let us take first the effects of warm water upon amalgamation. At the alluvial mines of the mountains of the interior of Otago, New Zealand, the use of mercury,§ the good friend of the miner all the world over, is hardly known, and the explanation given is that mercury will not act in the cold climate of that region. This is due to the use of hot water in cleaning up at both mines and mills. The idea is, of course, quite an erroneous one, though there is

* Near the spot where was found, on June 15, 1858, the Welcome nugget, which was sold by the lucky discoverers for £10,500. It weighed 2,159 ounces.

† Also the coarser crushing required to liberate the gold.

‡ Pure gold is worth £4 4s. 11½d per ounce at the London mint.

§ Discussed by the writer in "Alluvial Mining in Otago." *Trans. American Institute Mining Engineers*, Vol. XXI.

a substratum of truth in it from the fact that amalgamation is usually assisted by heat and retarded by cold, but within narrow limits only.* On the other hand, at Black Hawk, at over 8,000 feet above the sea level, in the bitter cold of the Colorado winters, the millmen will tell you that cold weather is better for amalgamation upon the plates than summer heat. Why? Because heat thins the amalgam, and the vibration of the mill due to the falling stamps causes the globules of mercury to run off and down the surface of the amalgamating tables, while cold (which thickens the amalgam) tends to keep it in position. From one point of view hot water is to be recommended. Slimes which will float on cold water will sink in warm water, owing to the expansion of the air bubbles, which float the fine dust and are the *raison d'etre* of the slimes. On the whole, however, while amalgamation (and here the amalgamation of gold is the only question discussed) is assisted by heat, yet below the temperature of boiling water the effects of a small rise are so slight that it is doubtful if the use of warm water is to be advised in ordinary gold stamp milling. It is certainly not to be recommended in summer at a locality having the climate of Ballarat, and therefore its use at the Britannia United is to be objected to.†

It is safe to say that the employment of condenser water is altogether objectionable. On suggesting that such water would be sure to carry grease with it the millman disagreed. At the New Chum Consolidated at Bendigo, where the condenser water was not used in the mill, I examined the launder which carried it outside the building and found that the bottom and sides were coated with a slimy ooze which could not but be prejudicial to amalgamation. Grease of any kind is the millman's worst enemy, for it coats the globules of mercury and prevents their coalescing; it makes "flouring," which is the subdivision of mercury into small particles, permanent. Yet at this (Britannia United) mill, where condenser water is used, the loss of mercury per ton of ore crushed is only 2.7 dwts., unusually small, and less than at the

*The amalgamation of gold, not silver, in ordinary stamp milling, not pans, is here discussed.

†At the time referred to it was summer and the temperature outside the mill 82° F.

neighboring Star of the East mill, where condenser water is not used. The explanation of these apparently contradictory facts is to be found in the addition of quicklime.

Five pounds of quicklime are added every 24 hours to each battery of five heads. As an alkali it is a solvent for grease, and though not intended as an antidote for the greasy matter contained in the condenser water, there is no doubt that it acts as such. Lime addition

At the Star of the East it is added to the blanketings previous to their reintroduction into the battery; it is also, as at the Britannia United, added directly with the ore fed into the battery. It is, indeed, in general use at the Ballarat mills with the purpose of keeping the amalgamating tables in good order. Lime as an alkali serves to neutralize the acidity of the battery water (produced by the reactions upon the partially oxidized sulphides when under the stamps), and in this way prevents the corrosive action of such water upon the iron of the gratings and the copper of the tables.

At the New Normanby mill in Ballarat East* the ore crushed is of a very free-milling character; it occurs coarse and in quartz almost free from pyrites. There is no concentrating machinery. The character of the gold is proved by the percentage obtained in retorting the amalgam, the yield of bullion being rarely under 55 per cent. and averaging very nearly 70 per cent. Four-fifths of the product of the mill comes from the mortar box, and of the remainder nearly all is caught by the first narrow strip of copper plate and the well immediately below it. The blanket washings are very poor.

The North Cornish mill is not in the town of Ballarat, though in the mining district of that name, but at Daylesford. The plant consists of 50 stamps, and the rate of drop varies from 70 to 75 per minute, the height of the drop being 8 inches. The depth of discharge or issue is extremely irregular. When starting with new dies or false bottoms the top of the die is approximately level with the bottom of the grating and the depth of discharge is practically nil, but as the dies wear down (they are 4 inches deep) the issue in-

* Near the famous Canadian lead, which yielded so many of the large nuggets.

creases to a maximum of a little over 3 inches. The mill crushes 90 long tons per day, or 2,450 tons per month.*

The amalgamation is effected by methods similar to those described as in use at the Star of the East. Scarcely 11 per cent. of the amalgam obtained comes from the mortar boxes. Much the largest proportion is derived from the skimmings of the wells and in the blanket sands. The latter are treated by Berdan pans, of which there are six. The tailings from the Berdans go to a Frue vanner for after-treatment.

This is a comparatively new mill, the oldest portion being five and the newest two years old. The quantity of ore in sight in the mine is such as to have led to the consideration of a further addition to the number of stamps. The mine has paid large dividends for a long period.† Notwithstanding these facts the mill is miserably incomplete. Although very favorably situated and having all the fall required for an automatic arrangement of its parts, it is unprovided with rock-breakers or self-feeders. In the feeding of the 50 stamps there are employed upon each shift 5 men at 30 shillings per week, making a total cost of £1,125 per year. The other end of the treatment shows equally grave defects. In spite of the fact that the concentrates are of unusual richness and that to them the shareholders practically owe their dividends, there are only 14 Frue vanners to treat the pulp coming from 50 stamps. The ore is one requiring very careful concentration, since after having passed over the amalgamating tables it still carries black slimes known to be very rich. For the saving of such material the Frue vanner is excellently adapted, but it is a machine which must not be crowded, and for the work to be done at the North Cornish mill 22 of these concentrators is the least number that can be employed consistently with good work.

On turning back to the comparative table it will be noted that the five mills whose figures are given show a general resemblance in their methods. They fairly represent existing colonial practice. It will be seen that the old Star of the

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* For the half year ending December 31, 1890, there were 14,664 tons crushed, yielding 4,386 oz. 18 dwts. in the mill, and 1,486 oz. 5 dwts. from the 269¼ tons of pyrites (concentrates) treated at the chlorination works.

† Up to the end of 1890, on a paid-up capital of only £4,000, this property has paid dividends amounting to no less than £85,500.

East mill, the New Normanby, and the North Cornish all have the same weight of stamp. The other two have unusually heavy stamps, and in this respect they are following the tendency which was to have been noted in California a few years ago, and like the California mills they, too, will probably ere long find it expedient to revert to a lighter pattern. This is an instance of the same ground being gone over twice and of the needless expenditure of time and money in trying experiments which some other district has already carried out. There is no worse waste than the waste of experience.

The Britannia United and the New Normanby make 12 drops per minute less than the other three, owing to the fact that the gold being coarser and more free the ore does not necessitate fine crushing. The fineness of the gratings indicates this. The height of the drop is practically uniform save in the case of the New Normanby, where, owing to the unusual coarseness of the gold and the absence of pyrites worthy of concentration, rougher stamping is permissible.

In the matter of the issue or depth of discharge there is that wide variation usually to be remarked in most of the colonial mills. It is a feature of milling the importance of which is too little appreciated all the world over. At the Britannia United and New Normanby mills there is an effort made to prevent too great a variation in the issue as the dies wear down, but at the North Cornish the difference is between zero and 3 inches. The effect of a shallow discharge is seen at the Britannia United, which, notwithstanding a much slower speed, has a relatively higher crushing capacity than the Star of the East.

The gratings or screens are all made of the same material, round-punched Russia iron. The coarsest sizes are naturally in use at the New Normanby and the Britannia United, the two mills whose ore carries the coarsest gold and in the most "free" condition. The North Cornish uses the finest grating, since the gold of the ore which it treats is the most intimately associated with the pyrites.

The simple character of the gold quartz of this district is very well evidenced by the coarseness of the crushing which it permits of.

In the matter of screens the Colonial mills have been keep-

ing to that follow-my-leader policy which is the keynote to all that is deficient in their modes of milling. A little consideration will lead one to the conclusion that wire cloth has a much larger area of discharge than punched iron, having openings of equivalent size. Actual practical tests have confirmed this deduction. The crushing capacity of many of the Ballarat mills would be increased 10 to 20 per cent. by the use of wire-cloth gratings, and the amalgamation would be in no way altered or increased. The little extra cost is much more than compensated for by the larger amount of ore which can be treated. The full benefit of the change can be best obtained by having a double set of gratings, so that while one set is in place in the battery the other can be dried and cleaned with wire brushes.

In the matter of concentrates it will have been remarked that the New Normanby ore carries no pyrites worthy of concentration, that the Britannia United mill obtains only 1 per cent., and even that is of comparatively low grade, while the North Cornish, which has much the most refractory ore, has also the richest concentrates. It should be added, however, that the closer work done by the Frue vanners as compared to that of the ordinary percussion tables at the Britannia United, assists in keeping up the grade of the concentrates obtained at the former mill. The fineness of the bullion tells the same story as the concentrates, that of the Ballarat mills being of unusual purity and better than that of the Daylesford mill. The retort percentage indicates more accurately than any of the other figures the character of the ore as regards the coarseness of the gold which it carries. Thus the New Normanby amalgam yields 70 per cent. of bullion, while the North Cornish produces the more ordinary proportion of 33 per cent.

The time of wear of the screens or gratings is very similar in the first four mills, but at the North Cornish it is decreased to nearly one-half. The explanation is not far to seek. It is to be found in a very shallow, but variable, depth of discharge. When new dies have just been placed in position the top of them is level with the bottom of the screen and the direct splash of the pulp is, of course, violent. The discharge is then allowed to increase to several inches. It would certainly be

well to make an effort to regulate the issue and to keep it more uniform. At present it varies from zero to 3 inches. It is probable that the extraction of the gold would be benefited by leaning rather toward the greater than the lesser depth of discharge. At the Britannia United the average depth of the issue is no greater, but the variation is between 1 inch and 2 inches. This explains why the gratings, assisted by the fact that they are also less fine, have a time of wear double that at the North Cornish.

The consumption of mercury is much less at the New Normanby and Britannia United mills than at the other three, because these two treat ore containing a minimum percentage of pyrites, and because, therefore, the crushing is less fine. The amount of water used depends upon the grade of the amalgamating tables, itself proportioned to the heaviness of the pulp. It is also largely dependent upon the extent of blanket surface. The North Cornish uses much less water than the others, because the blankets, being followed by Frue vanners, are shorter than at the other mills where simple percussion tables are used.

The consideration of the methods of this district lead one to the conclusion that the mills are not availing themselves as they ought to, and as was to have been expected from so energetic and so productive a mining center, of the improvements brought into successful practice during the last decade. At Ballarat there is neither want of capital nor an inadequate ore supply to excuse the miserable incompleteness of the mills, in so far as concerns appliances and arrangements having in view the automatic handling of the ore. For mining companies like the Star of the East and the North Cornish, both owning magnificent mines paying large and regular dividends, and possessing very considerable ore reserves, there can be no excuse for the non-employment of rock-breakers, ore-feeding machines, and a proper and adequate concentrating plant. They stand as monuments of what should be more truly called obstinate ignorance and perverse disregard of modern experience than dignified by such a word as "conservatism." It is very regrettable that for reasons, all of them illogical and untenable, the mills of such an important mining district should be so out of date and so incomplete.

In conclusion, therefore, it must be said that while the actual work is excellently well carried out, the mills of Ballarat are woefully behind the ideal both in that handling of the ore which immediately precedes stamping and in that after-treatment which succeeds amalgamation.

CHAPTER IX.

Gold Milling at Bendigo, Victoria.

This district has had the misfortune of undergoing more than one christening, which explains the fact that it is not so well known in the northern hemisphere as its neighbor Ballarat. It was called Bendigo when in the autumn of 1851 it was changed from a sleepy sheep run to an excited mining camp, but the first name subsequently gave way to the more English Sandhurst, by which it was known for several decades, until in 1891, by a general consensus of opinion, the original name was resumed.

Though the riches of the first-found alluvium were exhausted at a comparatively early period, the later discovery of gold-bearing quartz lodes of great value, of unusual permanency and of very peculiar structure, has made the Bendigo district the greatest "quartz-reefing" center of Australia. This gold field now contains 26 mines having shafts exceeding 2000 feet in vertical depth. Six shafts are more than 2500 feet, and one (Lansell's 180 mine) has recently passed the 3000-foot mark.*

Since the date of its discovery in November, 1851, this district has yielded 12,000,000 ounces of the precious metal, valued at £48,000,000 sterling, or $240,000,000.

In 1892 the Bendigo district produced 198,009 ozs. 4 dwts. 2 grs., of which amount 5,750 oz. 2 dwts. 0 grs were of alluvial origin, and 192,259 ozs. 2 dwts. 2 grs. came from the quartz reefs. During that year the dividends paid amounted to £268,263, being at the rate of $6.50 per ounce of gold produced, or over 30 per cent.

The average yield of gold per ton of quartz ore was 9 dwts.

* Since this was written these shafts have been deepened and there are now several beyond the 3000-foot mark, the 180 mine having reached a depth of 3350 feet.

23 grs., and the average contents of the pyrites or concentrates, 2 ozs. 5 dwts. 8 grs. The price of the gold bullion varied from £3 17s. 0d. to £3 19s. 0d. per ounce. There were at work in 1892, according to the report of the Secretary of Mines for Victoria, in this district, 1279 stamps, 105 concentrating tables, 8 Chilian mills, and 32 arastras.

The comparative table which follows will give the chief figures indicative of the mode of treatment at a number of the most representative mills in the district.

The Fortuna "crushing works" are the property of Mr. George Lansell, the leading mine-owner of the district. This mill is engaged in treating the ore coming from properties belonging to the proprietor, such as the "180," "222," and Comet mines, of others in which he holds a large interest, such as the Lazarus, and in doing a general custom business.

The plant consists of two portions, containing 48 stamp heads in all. Six mortars, of five heads, each are comparatively new, dating to 1888, while the remaining 18, in three mortars of six heads each, are old. The stamps weigh 900 pounds each, this total weight being distributed as follows: Disk or tappet, 66 pounds; shank or stem, 325; tophead or boss, 159; head or shoe, 198; false bottom or die, 152 pounds. The stem is 12½ feet long; 8 feet of 3¼ inches, and 4½ feet of 2¾ inches iron.

The speed averages 70 drops per minute, and varies from 68 to 75. The height of the drop varies from 8 to 9 inches. At the time of the introduction of new dies the issue or depth of discharge is 2 inches, but this increases as the dies wear away to a maximum of 6 inches.

The shoes are 10 inches high by 9¾ inches in diameter. The dies are 5 inches high. Steel shoes and dies were tried and were found to wear well, but being imported from England at a cost of £30 per ton, it was found more economical to use locally made cast-iron shoes and wrought-iron dies at a cost of £12 per ton for either. The wear per ton of ore is 16.4 ounces of the shoe and 6.2 ounces of the die. The tappets are screwed on; no keys are used. The order of the drop is not well adjusted, and approximates 5 and 1, 2 and 4, 3.

The crushing capacity of the mill is at the rate of 360 loads per week for the 30 heads, and 240 loads for the 18 heads.

The week has only six working days. A load of quartz ore is about equal to a ton of 2240 pounds. The rate per stamp is therefore two tons per day in the new section and slightly over that figure in the old part of the mill.

COMPARATIVE TABLE.

Name of mill.	Number of stamps.	Weight of each.	Number of drops per minute.	Height of drop.	Depth of discharge.	Capacity of stamp.	Capacity of mill in 24 hours.	Description of grating.	Holes per square inch in grating.
		Lbs.		In.	In.	Tons.	Tons.†		
New Chum Consolidated	30	895	72	9	3½	2.0	60	Round-punched Russia iron.	170
Lady Barkly*	40	965	68	9¾	3¼	2.1	84		115
Pearl	30	840	74	7¼	3¼	2.2	66		168
Fortuna	48	900	70	8½	4	2.1	100		143
Catherine‖	64	750 / 900	69	9	3½	2.1	134		143

Name of mill.	Percentage of concentrates.	Average contents per ton of concentrates.		Fineness of bullion.	Retort percentage.	Wear of grating.	Consumption of mercury.	Water used per stamp per minute.
	Per ct.	Oz.‡	Dwts.	Per 1000.	Per ct.	Days.§	Dwts.	Gals.
New Chum Consolidated	1½	2	11	955	46	17	7.75	**
Lady Barkly*	1¾	1	15	941	54	12	9.5	7½
Pearl	½	2	8	954	65	10	6.7	6½
Fortuna	....	Various.		958	55	7½	8.8	**
Catherine‖	½	3	4	952	66	9	7.3	4¼

The gratings or screens used are variously made of iron and steel plate punched with from 120 to 180 holes per square inch. A grating having 143 holes per square inch, and made by Goyere & Co. at the neighboring town of Epsom, is the one most used. The holes are 23-1000 inch in diameter. In the 30-head section the gratings have an average life of

* Full name, "South St. Mungo and Lady Barkly."
† Long tons, 2,240 pounds each.
‡ Silver contents negligible.
‖ Full name, "Catherine Reef United.
§ Working days of 24 hours each.
** No figures obtainable.

nine days, but in the old 18-head section this is diminished to six days. The stamps in the older portion of the mill are nearer the grating frame; hence the discharge of the pulp is more rapid, giving increased crushing capacity, but a diminution in the life of the gratings, which are subjected to a more violent abrasion by the pulp in the mortar box.

The percentage and value of the concentrates are not given because the ore supply comes from a number of mines and has a very variable composition. In 1890, 313 loads of pyrites were obtained and 20,582 tons of quartz crushed. A load of concentrates weighs from 25 to 30 hundredweights, so that the above amount is equivalent to, say, 460 tons. This does not, however, in any way properly represent the amount of pyrites in the ore, since the concentrating apparatus was at that time very incomplete. The actual percentage of pyrites in the quartz varies from ½ to 3 per cent.

The ore is fed into the battery by hand. Automatic feeding machines are not used in Bendigo, nor are rock-breakers.

The gold saving is done by the mortar box, by amalgamating tables, by wells, and indirectly by blankets. Mercury is added to the ore in the battery at the rate of 3 to 4 ounces per 5 heads per day when crushing 8 to 10 pennyweights ore. More is added when treating richer ore.

The amalgamating tables are covered with sheets of plain, not silver-plated, copper. In the old section they slope at 1 5-16 inches per foot, while in the new section the gradient is 1⅛ inches per foot. The tables are 5 feet wide and 13 feet long.

There are five wells in all; the lowermost three are shallow and do not contain mercury. The other two, at the head of the amalgamating tables, are 3 inches deep and 2½ inches wide.

The blanket strakes are 5 feet in the clear, divided into three strips, and have a length of 15 feet. In the 30-head section they slope at 1¼ inches per foot, in the old section 1 5-16 inches. The blankets are washed at an average interval of two hours. At the time of my last visit to the mill no further attempt at concentration was attempted, but since then the enterprising owner has introduced nine Gilpin County (Colorado) shaking tables, which are doing excellent work. The mill at night is lit up by electricity.

The Catherine Reef United, at Eaglehawk, is the oldest

mill of the five whose figures are given in the comparative table. It contains 64 stamps. The weight varies. Thirty heads arranged in six batteries weigh 900 pounds, so also do 24 heads in four batteries of six stamps each, while the remaining ten, divided into two batteries, weigh only 750 pounds each. The heavier stamps crush $2\frac{1}{8}$ tons each per 24 hours, but the light section only 2 tons.

The speed is regulated at from 68 to 70 drops per minute. The height of the drop is 9 inches, and is kept fairly constant. The depth of discharge or distance from the bottom of the grating to the top of the die is measured by 2 inches when new dies have been placed in position, and increases to a maximum of 5 inches as they wear down. The dies or false bottoms are 4 inches deep and $10\frac{1}{2}$ inches in diameter.

The grating in ordinary use has 143 holes per square inch. The 180 and 200 sizes are occasionally used. Their average life is nine working days.

The gold saving is done in the mortar boxes, to which mercury is added, by the wells and the copper plates, supplemented by blanket strakes. There is no concentration proper beyond the saving of the heaviest pyrites by blankets.

The tailings, owing to the lack of natural fall, are pumped into settling-pits.

Eight bottles of mercury, each containing 75 pounds avoirdupois, are consumed in a year, or at the rate of 7.3 pennyweights per ton of ore crushed. The mill only works during the daytime—16 hours out of the 24. In six months 19,550 tons were treated.

The ore comes from a spur formation in the Catherine Reef United mine. The gold occurs in the quartz in a coarse and generally free condition. The average mill return is as follows: In a fortnight of 12 working days 786 tons were crushed and yielded 146 ozs. 7 dwts. of bullion, together with 4 tons of blanketings carrying 12 ozs. 18 dwts. The gold has a caratage of 22, 3, 2, equivalent to about .952 fine; 250 gallons of water are used per stamp per hour.

The Lady Barkly mill is the joint property of the Lady Barkly and the South St. Mungo mining companies. Each company operates half the mill, which consists of two sections of 20 stamps. Each stamp weighs 9 hundredweights.

The stem weighs 336, the tappet 60, the boss 236, the shoe 196, and the die 109 pounds. The mill crushes at the rate of 84 tons per day. Twenty heads in 12 days (a fortnight), working 16 hours per day, put through 335 tons.

The gold saving is done by the mortar box, by copper-plated amalgamating tables, by wells, and indirectly by concentrators. Mercury is added to the battery at the rate of a teaspoonful per 8 hours when crushing the average (5 pennyweights) ore. The mortars of the two sections of the mill are of different pattern, those of the St. Mungo being the most roomy. As a consequence the latter have a slightly less crushing capacity but save a larger proportion of gold inside the battery. There is a considerable variation in the percentage of gold saved inside the mortar, but on an average it is about equal to that saved outside.

The wells are four in number. One of them is cast in the lip of the mortar box, and owing to the vibration to which it is subjected all the mercury which it contains is shaken out, and it therefore serves no useful purpose. Just above the plates there is another deep well. In addition there are two shallow ones, also holding mercury. No blanket strakes are in use.

The concentration of the pyrites in the ore is done by machines of local manufacture and known as Halley's percussion tables. They are regulated at a speed of 171 to 175 strokes per minute. The value saved in the concentrates represent 8 per cent. of the total yield from the ore. The amalgam retorts over one-half, about 54 per cent. The millstuff treated is very low grade, but owing to the width of the ore bodies the Lady Barkly Company has paid good dividends on 5 pennyweights material.

The Pearl mill belongs to the mining company of the same name. It was erected comparatively recently, viz, 1888. The plant consists of six batteries containing five heads each. Each stamp weighs 7½ hundredweights. The number of drops per minute varies from 72 to 76. The height of the drop is kept at from 7 to 7½ inches. The issue or depth of discharge has the variation noticed at most of the mills. When starting with new dies the depth is 2 inches, attaining a maximum of 4½ just before they are removed. The dies are 3½ inches

thick (occasionally 4 inches); they weigh 80 pounds each and are made of wrought iron. The shoes are made of cast iron; they have a depth of 9 inches and weigh 192 pounds each. The wear per ton of ore is at the rate of 19 ounces for the shoes and 4.7 ounces for the die.

The crushing capacity of the mill is at the rate of 400 tons per week of six working days. The mine is not, however, often able to supply the full amount of ore required.

The gratings are of the usual round-punched iron plate. The kind generally in use contains 168 holes per square inch. When working full time the gratings have an average life of 10 days.

The gold saving is effected by the mortar box, by amalgamating tables outside, by wells, by blanket strakes, and finally and indirectly by concentrating machines. Mercury is added to the ore when in the battery. Of the total gold obtained from the treatment 8 per cent. is the yield from the blanketings and concentrates, 7 per cent. comes from the wells, 20 per cent. is extracted on the amalgamating tables, and 65 per cent. is obtained from inside the mortar box.

A clean-up is made of the battery once per week, and of the copper plates outside once per fortnight. The amalgamating tables are covered with plain copper; they are 5 feet wide and 11 feet long, and they have a gradient of 1¾ inches per foot. The blanket strakes are subdivided into three longitudinal partitions, the total width being 5½ feet, having a length of 11½ feet. They have a slope of 1½ inches per foot. The residue from the washing of the blankets undergoes separation on straight sluices or "tyes," whence the sand obtained goes to the concentrators, and the pyrites is added to the concentrates from the shaking tables.

These last are of the ordinary variety (Halley) and are six in number. They are worked at a speed giving them 165 to 180 strokes per minute.

The order of the drop of the stamps is 5, 1, 3, 4, 2, but 5 and 1, 4 and 2 fall almost simultaneously. It will have been noticed that in spite of a very shallow discharge the largest portion of the yield is saved by the mortar itself. This, as is suggested by the high percentage of bullion obtained in retorting, is owing to the coarse character of the gold in the

ore. From the grating to the nearest point of the shoe the distance is 3 inches, between the dies ¾ inch, from the back of the mortar to the nearest point of the die 2 inches, and from the die to the front of the mortar, 1 inch.

The feeding of the battery is done by manual labor. In order to keep them supplied the 30 stamps require the services of two laborers per 8-hour shift, one of whom, a young fellow, gets 33s. ($7.92) per week, while the other, an older man, is paid 40s. ($9.60).

The country rock in which the quartz lodes occur forms a large proportion of the millstuff. It has a very variable hardness, from soft slate to quartzitic sandstone. An effort is made to mix the material so as to assist the regular working of the mill.

The New Chum Consolidated mill is the best in Bendigo. It was erected in 1889 and is in excellent working order. The motive power is obtained from a triple-expansion engine supplied with steam by two multitubular return flue boilers.*

The plant consists of 30 stamps, arranged in two sections of three mortars. Each stamp falls with a weight of 8 hundredweights. The boss or tophead weighs 193 pounds, the shoe 175 to 185 pounds. The speed varies from 70 to 75 drops per minute. The height of the drop is rarely changed from 9 inches. The depth of discharge is 2 inches at the time of placing new dies in position, and increases to a maximum of 5 inches as they wear down. The dies are 4 inches thick. The crushing capacity of the mill is at the rate of 725 tons per fortnight of 12 working days. The gratings or screens are made of round-punched Russia iron, containing 170 holes per square inch. The holes are 0.023 inch in diameter. The gratings last about 17 full working days. They would give better wear but for the vertical lines of weakness produced by the press employed in their manufacture.

The gold saving is done by the mortar box itself, by wells or mercury traps outside, by amalgamated tables, and indirectly by concentrators and blanket strakes. The mortar becomes an amalgamator by the addition, at regular intervals,

*This may appear hardly worth mentioning, but the fact is that boilers of modern design are rare in the colonial mining centers. The single flue Cornish boiler forms the prevailing type.

of free mercury to the ore, as it is fed into the battery. A teaspoonful—about 2½ ounces—is added to each five stamps every shift of eight hours. The distance from the screen to the shoe is 3½ inches. As a rule in this district it is from 4 to 5 inches. In the most recently erected plants there has been a tendency to make the mortar more roomy in order to increase the proportion of gold saved inside.

The amalgamating tables are lined with plain copper plate. Their length is 10 feet, their width 5½ feet, and their slope 1¼ inches per foot. The length is subdivided by a "well" or deep mercury trap, and three "ripples" or shallow catch-pits. The first piece of plate is 23 inches long, and its surface is broken at a distance of 8 inches from the mortar by the deep well above mentioned. It is 7 inches deep and is always kept full of mercury. It holds the contents of one flask, or 75 pounds avoirdupois. The ripples are distributed over the remainder of the length of the tables.

From the "ripple tables"—as the Bendigo millman often calls the amalgamated plates—the pulp passes not first over blankets and then to concentrators, but *vice versa*. The concentrators are Halley percussion tables worked at a speed of 180 to 200 strokes per minute. There are six of them or one to each mortar. Then come the blanket strakes, which have a total length of 14 feet 9 inches and a width of 5 feet 6 inches. The width is subdivided into three partitions. The slope is equal to a fall of 1⅛ inches per linear foot. The blanket residues are usually very poor, and consequently the blankets are only washed at intervals of eight hours. A test lot is occasionally sent to the chlorination works so as to determine what kind of work the concentrators are doing. A recent lot, resulting from a fortnight's crushing, amounted to only 4 tons, yielding 5 ounces of gold altogether. When found to be poor, as in this instance, it is the usual custom to return the blanket sand for retreatment by the concentrating machines.

The four consecutive fortnightly mill runs, shown on next page, will give an idea of the kind of work the mill does.

Thus 2900 tons were crushed for a production of 459 ozs. 8 dwts. in retorted gold obtained in the mill itself, and 95 ozs. 15 dwts. in melted gold extracted at the chlorination works. The ore, therefore, gave a total yield of 3 dwts. 4 grs. per ton.

Each "load" of concentrates is equal to about 27½ hundredweights, therefore the yield per ton was 1 oz. 16 dwts. The concentrates amounted to 1.8 per cent. of the weight of the original ore. The gold from the pyrites is .970 to .975 fine, while that obtained at the mill is from .950 to .960 fine. In retorting the amalgam yields 46 per cent. of its weight in gold. Of the total amount of amalgam obtained, 55 to 60 per cent. comes from inside the mortar box, and the remainder from the plates and wells outside. Of the amount saved outside the battery more than half is obtained from the deep mercury well. Of the total saving of gold affected by the mill, 81 per cent. comes by amalgamation and 19 per cent. by concentration.

Ore.	Yield by amalgamation.		Yield by concentration.		
	Bullion.		Loads of concentrates.	Yield in gold.	
	Ozs.	Dwts.		Ozs.	Dwts.
737 tons,	102	15	10	22	12
710 "	100	5	9	28	5
750 "	107	2	9	19	5
703 "	149	6	9	25	13

The loss of mercury is at the rate of one bottle (75 pounds) per 6 to 7 weeks. This is equal to a consumption of 7¾ pennyweights per ton of ore crushed. About 150 ounces of mercury are in use for each battery, with its series of wells and plates.

The following additional particulars will be of interest: The feeding of the ore is done by hand, and done badly. This will be referred to again. The shoes weigh 175 to 185 pounds; they last 9 to 10 weeks, crushing 115 tons of ore; when worn out they weigh 38 pounds. The wear is therefore at the rate of 19.7 ounces of iron per ton of ore. The dies are 4 inches deep and 10 inches in diameter. They are square in section, with corners beveled. When new they weigh from 96 to 100 pounds; when discarded, 26 to 35 pounds; they last 28 weeks, crushing 335 tons. The wear is therefore at the rate of 3.4 ounces per ton of ore. The shoes are made of cast iron and the dies of wrought iron, provided by the local foundries at a uniform rate of £12 per ton.

After a half year's operations the copper plates are overhauled and cleaned with acid. At a Christmas clean-up this

process yielded 646 ounces amalgam, giving 235 ozs. 4 dwts. of gold from the treatment of the 18 copper plates. This cleaning spoils the gold-saving qualities of the plates, because its robs them of their surface of gold amalgam. It is done in order to squeeze out an extra dividend.

There is not sufficient fall to carry away the tailings. They are pumped into a first or "slum" dam, where they are allowed to settle, then the clear water is pumped into a second dam, whence it is returned to the mill.

The New Chum Consolidated Mining Company is one of the very best managed mining concerns in Australasia, as the following figures testify: For the half year ending June 30, 1890, there were 9586 tons sent up from the 1800-foot level, yielding 1722 ozs. 19 dwts. of gold at the mill, and 278 ozs. 8 dwts. (from 106 loads) at the pyrites works. The total value of the yield was £7943 5s. 9d. The average of the ore was 3 dwts. 14 grs. only, but this gave a profit of £1510 6s. 9d., equivalent to a shilling dividend on each of the 28,000 shares of capital stock. The yield was 16s. 9d. (say, $4) per ton, and the cost 13s. 5d. (say, $3.22) per ton.

The tailings of the mill have been carefully sampled and assayed. They are said to carry only 1 dwt. 4 grs. per ton. The right to treat them is sold to Chinamen for £8 5s. per month, one of the conditions being that the Chinamen shall maintain the dams in good condition.

The five mills which we have passed in review are fairly representative of the best practice of the district. The Catherine Reef United is one of the oldest crushing plants, the New Chum Consolidated is one of the most recently erected, while the other three belong to intermediate periods.

At Bendigo, as in the most of the Australian mining regions, the mines and mills are closed down on Sunday, and the week, therefore, has only six working days. This pleasant custom does not seriously interfere with the work in the mines, for they are comparatively dry; nor at the mills, for the supply of ore does not require the use of the seventh day. It will have been noticed in the course of the detailed description of the several mills that many of them do not work continuously throughout the 24 hours. The majority of the mills, except in periods of unusual activity, as during the past 18

months, work two-thirds time, or 16 hours. That this state of things should obtain is due to the desire, easily understood, of each mining company to possess its own mill and to treat its own output. The frequent fluctuation in the magnitude of the ore production causes the necessity for this intermittent operation of the mills, which are themselves, as a rule, proportioned in their capacity to an output in excess of the average supply that the mines can afford. The production of most of the mines is spasmodic, due to the fact that their development is ill-regulated and their ore reserves, at any given time, very small. No serious attempt is made to maintain a uniformity in the output; therefore a mine which is producing a full mill supply for a certain period may suddenly become non-productive until fresh development work leads to the uncovering of new bodies of ore.

This is a mistake, of course, not only in respect of general management, but also in regard to the mill itself. A mill can be run at less expense per ton of ore when it is kept continuously at work than when working at intervals. Periods of idleness must be injurious to the machinery, and not only to the delicate mechanism of the engine, but also to the stationary parts of the plant. Rust and dirt find a ready entrance everywhere when a mill is working 16 hours and idle the remainder of the 24.

The comparatively small size of the mills calls for comment. The average number of stamps is 30. In one case—the Lady Barkly and South St. Mungo—two mining companies share one mill. This is a step in the right direction. If there were fewer mills, but larger ones, if the number of stamps now working in two or more plants were consolidated under one roof, there would result an economy in labor, power, and superintendence which would help very considerably to decrease the cost of milling per ton of ore.

The mills are well-built, neat machines. They are all of local manufacture, and reflect much credit upon the Bendigo foundries. Their framework is entirely of iron. (See accompanying drawings.)* This adds much to their appearance, but it has often been questioned whether it does not also increase the vibration produced by the fall of the

* Which I owe to the courtesy of the manager of the Victoria Foundry, Bendigo.

stamps. It is generally supposed that a wooden frame is less rigid, and therefore takes up the vibration better than iron, which, on the contrary, is supposed to become crystalline and therefore brittle. The effect of the vibration upon the structure of the iron is a point which has been matter for controversy. This is not the time to discuss so difficult a subject. The experience of the Australian mills does not sustain the idea that an iron framework is objectionable. The iron of the stamp stems becomes crystalline and breaks do occasionally occur; so also with the cams, but not more often than in the case of wooden-framed batteries. The Garden Gully United mill, for instance, which was one of the first iron-framed plants erected in this district, is not fully 20 years old, but is still working very smoothly.

Before entering into a discussion of the character of the work done and the milling methods employed, it will be necessary to look at the nature of the ores treated. The Bendigo reefs are in slate and sandstone country. The millstuff contains a very large proportion, varying from 25 to 75 per cent., of "mullock" or country rock. On the whole, I think the sandstone predominates over the slate, but the ratio is constantly changing. The sandstone is, of course, the harder of the two, but it breaks in a granular way, which is more favorable to amalgamation than the tendency toward the formation of slimes which characterizes the crushing of the slate. In many of the mills an effort is made to mix the two.

The gold exists in a quartz more white than that of the free-milling ores of the Californian foothills. The amount of sulphides occurring in the ore is small but very variable. Upon an average the millstuff contains less than 2 per cent. of pyrites. The other sulphides—blende and galena—are present in insignificant proportion. The quartz itself breaks readily; it often has a sherd-like fracture, causing it to splinter easily. The gold is essentially coarse; the retort percentage at the mills (rather over than under 50 per cent.) is indicative of this fact. The gold is also of high caratage, as shown by the bullion obtained at the mills, this being rarely under .950 fine. The gold as it exists in the ore is not rusty, but bright and in a condition to be readily and quickly amalgamated.

The silver which accompanies it is in such minute quantity as to be negligible.

The millstuff crushed and treated by the Bendigo mills is therefore essentially free milling. The extraction is, as a rule, high. As to the values which escape in the tailings, I estimate them at from 1½ to 2 pennyweights.

Mr. J. Cosmo Newberry, the government analyst, states that "the average tailings of the quarz-mining districts of the Colony can be considered as containing between 2 pennyweights to 2½ pennyweights per ton, while in some districts, as, for instance, Sandhurst (or Bendigo), where the methods of treatment are good, the loss, on the average, is not more than 1½ pennyweights per ton." The mean average of the ore treated at the mills has, for a period of five years, varied from 9 dwts. 2 grs. to 9 dwts. 23 grs., so that a loss of 1½ pennyweights would represent an extraction of 85½ per cent., a result which is decidedly good when compared to the work done in other mining regions. Though good in comparison, it yet easily falls short of what it might be. The mere fact that Chinamen can find it profitable to treat the tailings discharged by the mills indicates that the gold is in such a condition as to render its loss avoidable if the proper methods were employed. The loss is due to the irregular pulverization caused by bad and uneven breaking and feeding of the ore. This I hope to prove.

In considering the milling practice it will be well to distinguish between the actual operation which extracts the gold and the disposition of the parts of the machine which does the work—that is, between what is chemical and metallurgical, and what is essentially mechanical. The former may not admit of adverse criticism, and the treatment may be considered technically correct, but the latter falls far short of attaining any perfection of automatic work and is decidedly bad.

At all the mills a large part, nearly one-half, of the total amount of amalgam obtained is derived from the saving effected by the mortar box itself. There are no inside plates, the gold being arrested by the action of gravity, assisted by the agency of the free mercury added from time to time to the ore in the battery. The tendency in this locality at the

time of my last visit was to augment the proportion of gold to be saved within the mortar box by making the latter more roomy. The distance from the screen or grating to the nearest point of the shoe is about 5 inches, and the latest designs indicate the intention to increase this figure. It is a fault in the ways of these old-established Colonial mining centers that, owing to the fact that the mining and milling are not under the direction of technically trained engineers, the mode of construction of the mills has necessarily to be left almost entirely in the hands of the foundries. The millmen attend to the extraction of the gold in the ore, which it is their business to crush, but they do not concern themselves with the details of the design of the machine which does the work. The foundries, very naturally, change their patterns as little as possible, and there seems to be an unexpressed idea that the ores must adapt themselves to the mills rather than the reverse. In this respect Bendigo is not to be considered unique. The same thing is done elsewhere.

In general, the methods of milling show a lack of progressiveness and an absence of that acquaintance with, and immediate utilization of, modern improvements which characterizes the mining regions of the great West. That this is no unfair commentary is indicated in a very marked degree by the deficiencies of the mills in respect of the arrangements designed to promote an automatic handling of the ore. It may well be asked, Why do the mills, without exception,* use shaking tables which do not discharge their concentrates automatically, seeing that there are so many, and no more expensive, concentrators which will do this work without the aid of a boy and a shovel? The reply to this query generally comes somewhat in the following form: That the boy is the deserving son of a deserving old father; that he does not receive high wages; and that it is just as well to give work to such young fellows. The weakness of the logic does not manifest itself to the old Colonial, but, of course, the argument is quite untenable. The fewer boys and shovels you employ in your mill the more automatic as a machine it becomes,

* I refer to the time of my stay at Bendigo. Since then Mr. George Lansell has introduced Gilpin County "bumpers," or shaking tables, at the Fortuna mill. They are working very satisfactorily.

and the less will be the cost of treating the ore, the bigger will be the dividends, the more numerous will be the mines and mills that will be operated, and the greater the chances of employment for every one in the district.

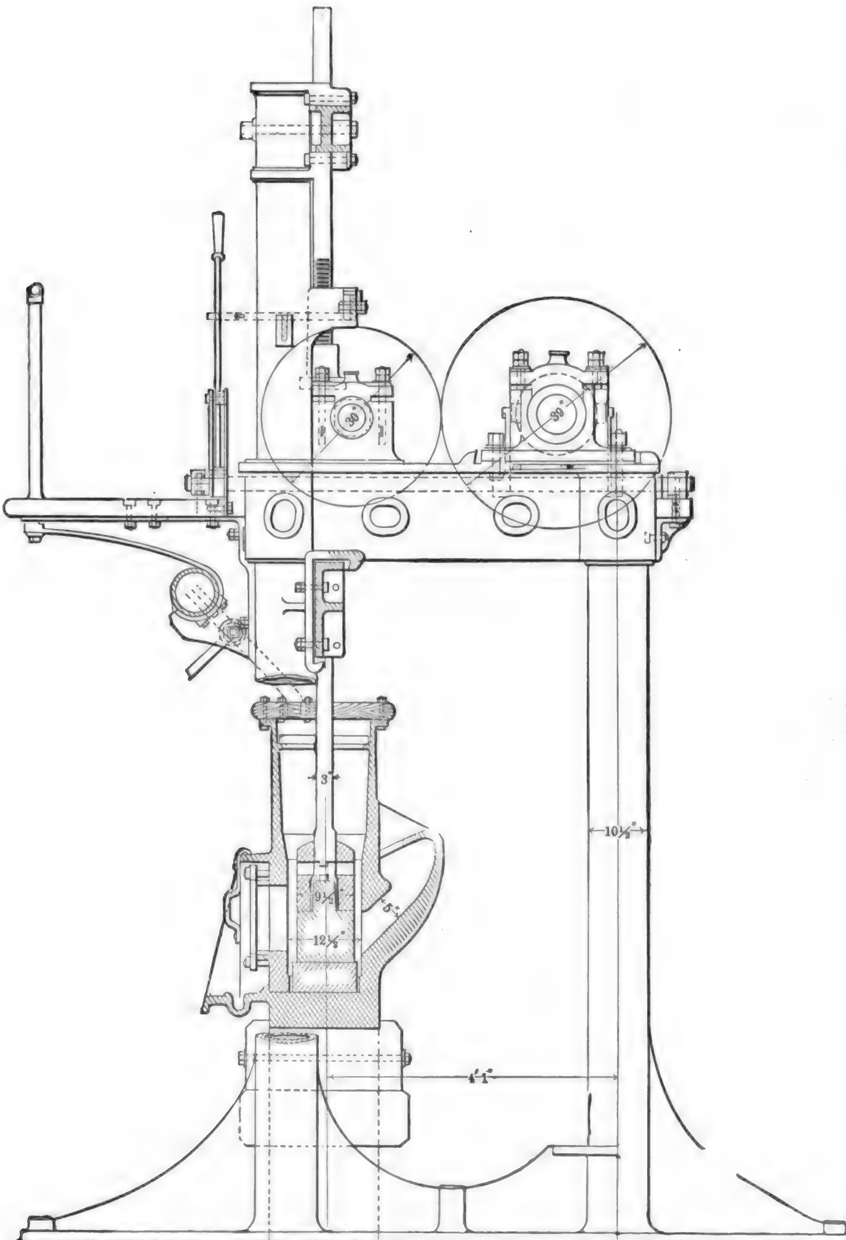
This is, however, a small matter compared to the absence in every mill of rock-breakers, grizzlies, and self-feeders. It is impossible not to feel that this is a disgrace to any modern mining district. But Bendigo is not a solitary sinner. The gold production of the great mining colony of Victoria, namely 60,000,000 ounces in 40 years, places it in the forefront of the mining regions of the world, and the results, magnificent as they are, have been obtained by the work inaugurated and carried out by men who are second to none in energy and ability. Nevertheless, in the whole Colony there are to-day only 12 rock-breakers, and of these I know of at least four which are in mills that are idle. To me it is incomprehensible that there should be in this respect such a lack of keeping step with that modern progress which has been no more marked in any department of human activity than in that of the mining industry.

While at Bendigo I had many serious discussions over the rock-breaker and self-feeder question; so many that I am afraid I was mistaken for the advance agent of a machinery firm. But, you say, Queen Anne is dead! It is surely a waste of time in the year 1896 to be discussing the advisability of employing rock-breakers and self-feeders in a gold-quartz mill. It may, however, do us good and be of service to our cousins in Australia if we again inquire into the question as if it had not been settled long ago.

Let us first take the cost of breaking and feeding at two of the best of the Bendigo mills:

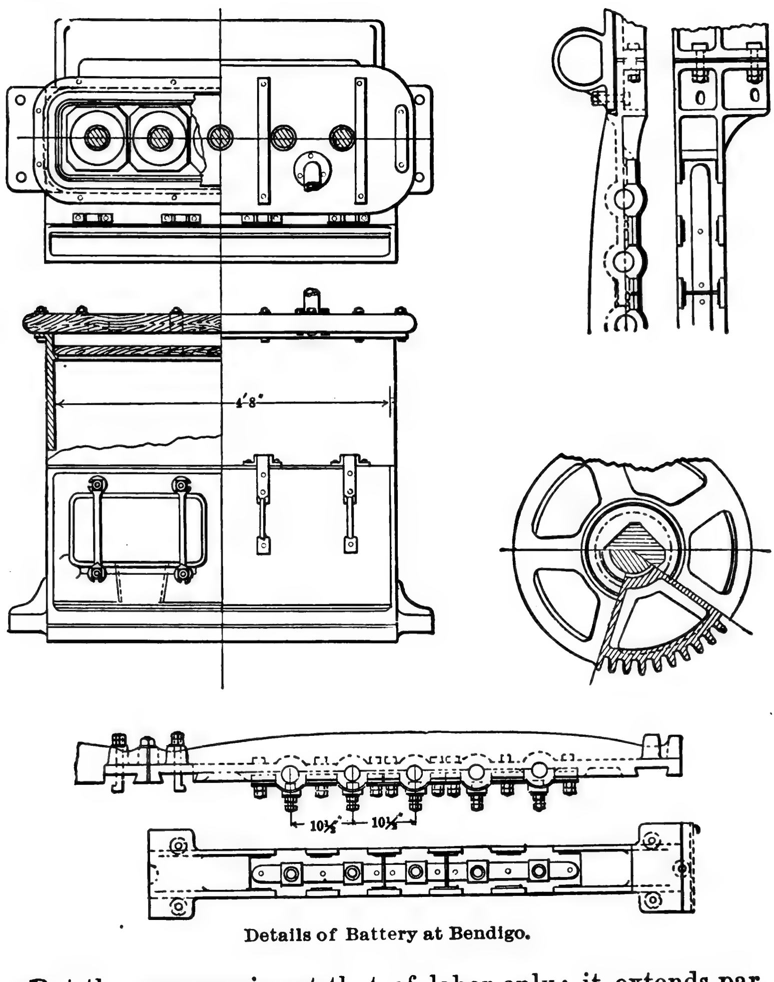
	Stamps.	Number of feeders per shift.	Wages per week.	Cost per annum.
New Chum Consolidated . .	30	3 boys.	£9	£468
Pearl	30	1 boy and 1 man.	£10 19s.	£569

Boys at £1 per week are put down as inexpensive extras, but in a year the wages paid to them make a sum greater than is required to purchase and erect a full equipment (it would be six in each of the above instances) of the most expensive (but also most effective) of automatic ore-feeding machines,



An Iron-framed Battery as Erected at Bendigo.

and a rock-breaker of such a capacity as would break a 24-hours' supply of ore in 10 hours, leaving the pulley which drives it by day free to operate a dynamo to illuminate the mill by night.



Details of Battery at Bendigo.

But the economy is not that of labor only; it extends particularly to wear and tear. Good hand-feeding is more of a day-dream than an actuality; it is not found at Bendigo, for there the feeding is done badly and irregularly. I have often stood by watching the boys assisting with the blows of a

sledge hammer the entry into the battery of pieces of rock, 4 to 6 inches big, which were too large for the feeding hole and which they were too lazy to break up previously. They are not to be blamed so much as the system which makes them possible.

Uneven breaking and irregular feeding add immensely to the wear and tear of the whole mechanism of the mill. A stamp which one moment is falling on soft pulverized particles of ore is at another instant dancing upon a hard, large piece of rock, upon which it descends more than once before breaking it. If the stamp falls full upon it no work may be done, and that is all, save for the jar to the whole machinery; but if it strikes it on the edge a piece of the shoe is in all likelihood chipped off. This can be proved by the actual wear of the shoes, as expressed in ounces of iron abraded per ton of ore crushed. The die is not affected to anything like an equal degree, because the layer of ore upon it acts as a cushion and tends to equalize the wear. Careful inquiry shows that while at the New Chum Consolidated and Pearl mills there are 19.6 and 19.4 ounces, respectively, of the shoe worn away for every ton of ore crushed, at Grass Valley (California), the Black Hills (South Dakota), and Mammoth (Arizona), the wear in no case exceeds 7½ ounces per ton of ore. In spite of the variety of castings, of the varying hardness of ore, and of other changing conditions, the evidence is wonderfully harmonious in accentuating the fact that the use of proper rock-breaking and ore-feeding machines very much decreases the wear and tear of shoes and dies. The time lost in a year by the more frequent stoppage of the work of the stamps in order to replace worn-out shoes with new ones, is by no means inconsiderable and means a monetary loss which must be added to that caused by the excessive waste of the metal of the shoes.

The time of service of the gratings or screens is also seriously diminished by the bad feeding and rough breaking of the ore. So long as man is human there will come times when the feeder, taking a rest or wanting a smoke, will fill the mortar box with ore, so as to keep the stamp supplied during the interval which he requires. High feeding is a potent cause in diminishing the life of the screen. Facts and figures

bear out this line of argument. At Bendigo a grating lives to pass through 110 tons of ore; but in the principal milling centers of America, all of them using improved rock-breaking and ore-feeding appliances, the screens, under ordinary conditions, last during the discharge through them of from 200 up to 300 tons. The maximum figure is reached at mills which crush three tons of ore per stamp, but even at Grass Valley, where the millstuff is certainly very much harder than that of Bendigo, but where the rate of crushing is about the same, though the screens used are of greater fineness, they give an average service nearly twice as good as that obtained at the Pearl or New Chum Consolidated mills.

More important, however, than the wear and tear of screens, shoes and dies, and other working parts of the mill, is the effect produced upon the crushing capacity of the stamps. By using rock-breakers, grizzlies, and feeders in place of the primitive barbarism of sledge-hammer, boy, and shovel, you save the stamp that breaking of the larger stones of ore which is at present its hardest and most wasteful work. The Bendigo mills would, I believe, judging from experience elsewhere, increase their crushing capacity 25 per cent. if properly equipped. This means nothing more nor less than a diminution equivalent to 20 per cent. in the cost of milling.

The stamp battery would also become a better amalgamating machine. At present it is a breaker, pulverizer, and amalgamator, all combined. If the first and roughest work, that of breaking, were omitted and delegated to a machine especially designed and constructed to do this particular part of the operation both well and quickly, the stamps would pulverize more evenly and the mortar box would become a more efficient amalgamator.

One could continue the discussion by referring to other parts of the mill, for regularity and evenness of working are as essential to the stamp battery as to any other machine, and the want of it is seriously felt in every portion of the contrivance which the miner uses to crush his ore and to extract his gold. But enough has been said. This feature of the mills would not perhaps have been worthy of such lengthened consideration were it not that Bendigo is the greatest stamp-milling center of Australasia, having gold mines which,

for the extent of their development in depth, are without a parallel and which promise a future of long-continued productiveness.

In conclusion, while it may be said that the milling practice of Bendigo is intelligent in its methods and successful in the extraction of a large percentage of the value in the ore, it must also be added that owing to the absence of certain modern improvements of unquestioned usefulness the results obtained, while good, are yet got at a quite unnecessary waste of labor and material.

CHAPTER X.

Double-Discharge Mortars in Victoria.

The Ovens is one of the main tributaries of the Murray, the only great Australian river. Its source is in the Australian Alps, and its headwaters flow through the most rugged and picturesque portion of the colony of Victoria. This district is northeast from Melbourne, and near the border dividing Victoria from its neighbor, New South Wales. In the early fifties the mining camps of Bendigo and Ballarat sent forth bands of pioneers who penetrated the hearts of the snow-capped ranges and found placers of extraordinary richness, which made the Woolshed, the Buckland, and other localities in the Ovens district, rank among the very best discoveries of that golden age. Now, however, the former glory has departed, the Mongolian has come to pick up the crumbs which have fallen from the table of the Caucasian, and the more steady routine of quartz-mining communities has replaced the feverish excitement of alluvial diggings. The mines are scattered over a country the most mountainous in Australia, and the mills stand beside streams whose perennial flow is in pleasing contrast to the dusty dryness which is characteristic of most of the mining centers of Queensland, New South Wales, and Victoria.

The methods of milling have been derived for the most part from Clunes. The mills themselves are usually small and do an irregular custom work, dependent upon a precarious and uncertain ore supply obtained from the small mines whose white waste-heaps dot the blue of the forests of eucalyptus ("the bush") which cover the surrounding hills.

In the accompanying tabulated statement I have given the chief figures illustrative of the methods in use at five mills, of which only the first does not do custom work.

COMPARATIVE TABLE.

Name of mill.	No. of stamps.	Weight of each.	No. of drops per minute.	Height of drop.	Depth of discharge.	Capacity per head.	Capacity of mill.	Description of grating.	Fineness of grating, in holes per sq. inch.
		Lbs.		In.	In.	Tons.	Tons.		
Harrietville	25	700	70	8	2	1½	37†	Round-punched Russia iron.	240
*Oriental	16	784	55	9	8	1⅓	20		220
*Hillsborough	8	784	60	9½	3	1¼	14		200
*Railway	20	720	60	9	4	1⅜	32		200
*Stephens	6	840	50	9½	4½	1½	9		250

Name of mill.	Percentage of concentrates.	Gold contents of same.	Fineness of bullion.	Retort percentage.	Wear of gratings.	Loss of mercury per ton of ore.	Consumption of water.
	Per cent.	Ozs.	Per 1000.	Per cent.	Days.	Dwts.	Gals.§
Harrietville	1	5	965	36	18	19‡	5
*Oriental	**	**	940	52	17	8	4
*Hillsborough	2	1½	940	50	18	4	3½
*Railway	**	**	950	45	20	8	4
*Stephens	**	**	945	48	18	8	4½

The Harrietville mill is much the most important in the district. It is the property of an English company owning a very extensive group of mines, among which may be mentioned such euphonious names as "Tiddle-Dee-Addle-Dee," "Jackass," "Monsmeg," etc.

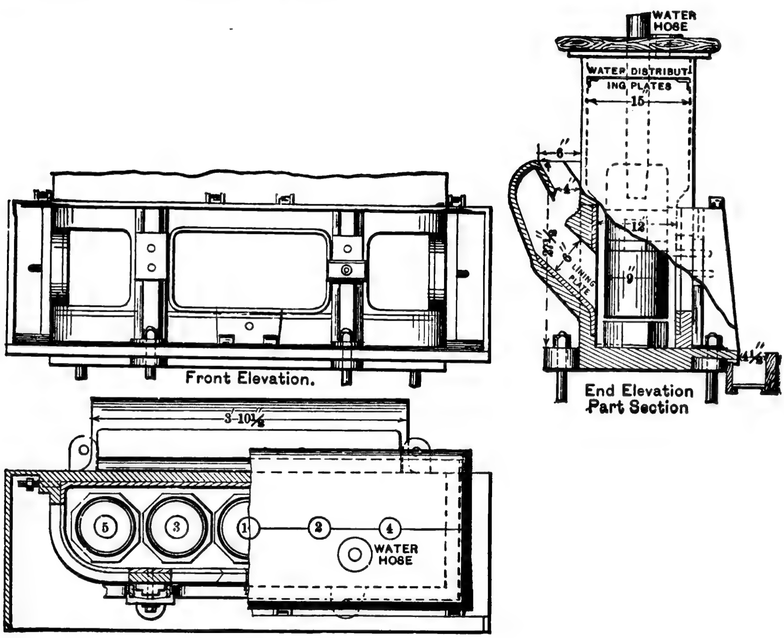
The plant consists of 25 heads, in two sections of 10 and 15 stamps respectively, separated by the overshot waterwheel which supplies the motive power. The wheel has a diameter of 40 feet and a breast of 5 feet.

Each stamp weighs 700 pounds and drops 70 times per minute. The height of the drop averages 8 inches. When

*Custom mill.
† Long tons, 2240 pounds.
‡ Including pans.
§ Per stamp per minute.
** Not saved.

new dies have just been placed in position, the depth of discharge (the distance from the bottom of the grating or screen to the top of the die or false bottom) varies from one-half to one inch, depending upon the amount of sand packed underneath the dies. On measuring the depth of discharge in several batteries at the close of a month's working, I found it to be 2¼, 3, 1, 1¼, 1, 2¼, 1¾, or an average of 1¾ inches.

The entire mill treats 1100 tons of 2240 pounds per month. Each stamp crushes 1½ tons per 24 hours.



Plan, Part Section.

Double-discharge Mortar Used at The Harriettville Mill.

The coffer or mortar box is 5 inches deep, while the dies, which are octagonal, are 4 inches thick. The shoes have round tongues, and are 9½ inches in diameter by 9 inches high. A shoe weighs 172 pounds, and a die 84 pounds. Both are made of best quality white iron, fagoted, not cast. This costs 16 shillings per hundredweight (112 pounds). The shoes wear evenly, but the dies soon develop an irregular surface ("cupping") and exhibit much variation in their time of ser-

vice. The average wear of iron per ton of ore crushed is at the rate of 9.8 ounces of the shoe and 3.4 ounces of the die. The ore being of comparative softness, the wear of the shoe must be considered as excessive. This result is due to two causes, the non-employment of a rock-breaker and the use of an identical material in both shoe and die. By the more uniform breaking of the millstuff the shoe can be saved much violent work, and by making the die of a metal less hard and more tough than the shoe, the latter would be found to last longer and to cause the die itself to retain a more even wearing surface.

The coffer is of peculiar design, and is provided with an end discharge, as is illustrated by the accompanying drawings, which I owe to the courtesy of the manager, Mr. Thos. G. Davey. The clear space inside the mortar is 4 feet 6 inches long by 1 foot wide. The interior is protected by a cast-iron lining 1 inch thick, and divided into four parts. These are shown in position in the section elevation. (See illustration.) The bottom of the mortar is flush with the amalgamating table outside. A part of the front edge or lip of the mortar box is removable, and allows of the easy introduction or removal of the dies.

The grating frame is in three sections, of which the two frames at the ends are curved, but afford a discharge surface similar in extent to that of the front, which is straight and has a length of 2 feet. The screen itself is of round-punched Russia iron. That at the ends has 175 holes per square inch, while that in front has 240. The time of service is slightly in favor of the front grating. A set lasts from under three weeks to nearly a month—that is, during the crushing of from 125 to 200 tons of ore. In this mill, as in many others which came under my notice, complaint is made of the weakening of the gratings by the perpendicular lines formed by the action of the press used at the time of their manufacture. The gratings are not fixed to a frame, but are kept in place by an iron clamp.

The gold saving is done in the mortar box itself, by outside amalgamating tables, by wells, and indirectly by shaking tables, the concentrates from which are first roasted and then treated by amalgamation in pans.

There are no amalgamating plates inside the mortar. Mercury is added to the ore fed into the battery, in quantities varying with the richness of the millstuff. The average amount is about one ounce of mercury per battery (of five heads) every half hour. The regulating of this addition is determined by the examination of the plate which forms the head of the amalgamating table. Every four hours this is inspected. If it be "moist," less mercury is added to the ore in the battery; if it be "dry," more is introduced.

The amalgamating tables are 12 feet long and 6 feet wide. They have a slope of seven-eighths inch per foot.* The total length is distributed over four subdivisions, of which the two uppermost are lined with silver-plated copper and the two latter with plain copper. The first or apron-plate is 22 inches long, and the second 3 feet.

A variation in the arrangement of the plates of the tables of two adjoining batteries enabled an interesting comparison to be made. At No. 5 battery the succession of plates is silver-plated copper, plain copper, plain copper. The middle one of these came from the old Monsmeg mill, was thoroughly amalgamated, and in first-class condition. At No. 4 battery the order was silver-plated copper, silver-plated copper, plain copper. After a year's working with ore of identical character it is found that the plain copper forming the third plate of No. 5 battery is well amalgamated, while the corresponding plate of the same material at No. 4 has not yet become whitened by amalgam. This proves that the second plate at No. 5—viz, plain copper—is not arresting gold and amalgam so successfully as the corresponding plate—viz, silver-plated copper—at No. 4 battery.

The amalgam is cleaned up every three days. Immediately following the first length of plate there is a drop-well 3½ inches deep. There is also a shallow well or ripple following this drop-well and succeeding each of the other subdivisions of the tables. All are charged with mercury and cleaned up once a week. Three bottles are in use for each set of tables. Thus 15 bottles are in use for the entire mill. The loss of mercury amounts to about 75 pounds avoirdupois per 1100

* Such a slight inclination of the plates is rendered practicable by the large amount of water used in this mill.

tons of ore crushed, being at the rate of 19 pennyweights troy per ton. This includes that consumed in the pan amalgamation of the concentrates. In the mill proper the consumption would be about 8 pennyweights.

There are no blankets below the tables, the pulp passing on at once to the shaking tables. There are five of these. They are the usual colonial variety of the Rittinger percussion table, and are not nearly so effective as some others designed on the same principle, as, for instance, the "bumper" of Colorado. The speed is regulated at 135 strokes per minute. The distributor of each concentrating machine is lined with old copper plates which are intended to arrest floured quicksilver and escaping amalgam. The ore yields about 1 per cent. of concentrates, consisting mainly of iron pyrites. The concentrates contain 5 ounces of gold per ton, or at the rate of 1 pennyweight per ton of ore crushed by the mill.

The general clean-up takes place on the last day of each month, and requires six hours for its completion. The dies are taken out and any adhering amalgam is scraped off. The sand inside the mortar is collected and washed over the amalgamating tables. This serves to catch most of the amalgam. The sand passes on to the shaking tables, whence the heaviest portion is returned to the battery when the mill is restarted. Of the amalgam obtained, 33 per cent. is collected inside the mortar boxes; of the remaining two-thirds, 8 per cent. comes from the wells and 58 per cent. from the amalgamating tables. Of what is saved on the plates fully 90 per cent. is yielded by the first length of the plate. Of the total yield of gold 86 per cent. is extracted by amalgamation and from 7 to 12 per cent. is saved in the concentrates. The retort yield of the amalgam varies from 25 to 52 per cent., averaging 36 per cent. The bullion is of high caratage, equivalent to .965 fine. Upon measurement it is found that the consumption of water is at the rate of 5 gallons per stamp per minute. This comparatively large amount is necessitated by the clayey character of the ore, the use of the end discharge, and the flat grade of the amalgamating tables.

The framework of the mill consists of iron standards of a comparatively light pattern. Owing to the care taken in the building of the foundations there is, however, no excessive

vibration. The tappets or discs are kept in place by a key and not by the old discarded, but more common, Colonial device of a screw. It was found here as elsewhere that while screw tappets are very excellent in theory, and while they may answer admirably when first put in position, as soon as they become the slightest bit loose, which cannot be prevented eventually, the screw gets instantly worn and is soon ruined. This necessitates too frequent stoppage for the cutting of a fresh thread.

The order of the drop of the stamps varies in the two sections. Fifteen heads drop in the order of 5, 1, 3, 4, 2, while ten fall in pairs, 5 and 1, 4 and 2, 3. The latter style is, unfortunately, too common in the Colonies. I noted that the stamp made a complete turn in from four to seven drops.

This is an excellent mill excellently managed; but it has one serious defect, a defect only too common in Australian mills. I refer to the absence of a rock-breaker. The Harrietville plant is in advance of many of the Colonial mills in being equipped with self-feeders, which, while simple, perhaps crude, in design, are yet effective in practice. For the absence of a rock-breaker there can be no excuse. The ore, it is true, is of less than ordinary hardness; most of it is small when broken in the stopes of the mines, but there is a proportion of larger stones sufficient to prevent anything like uniformity of size and to cause an excessive wear of the iron of the stamp shoes. For breaking ore a machine constructed upon the principle of a multiplied lever must necessarily be better adapted than one designed on the idea of a falling weight; hence the rock-breaker is better qualified to break ore than is the stamp. (Pulverization is another question.) By compelling the latter to do work which should be previously done by the former you produce unnecessary waste of the material of the shoes, dies, screens, and other wearing parts; you seriously diminish the crushing capacity of the mill and also interfere with the regular operation of the amalgamation which saves the gold.

We have seen that the mortars in use at this mill are designed so as to have a discharge at the two ends, as well as in front. It will be remembered that at Clunes the batteries have both a back and front issue. These variations from a

Harrietville Mill, the Ovens District, Victoria, Australia.

dull uniformity are interesting. At the Harrietville mill the end discharge is certainly successful. If it does nothing more it enables the use of copper tables of an unusual width, and by so doing it increases the area of amalgamating surface and the thin distribution of the pulp. An amalgamating table 6 feet wide and 12 feet long is a sight to gladden a millman's heart. As observed by me the wash of the pulp over the tables was very regular in speed and even in distribution. The Colonial millman will generally hasten to condemn the use of an end discharge. The reason is not far to seek. It is ordinarily attempted under the very unfavorable conditions afforded by a mortar box of rectangular shape. The result is that the issue through the end gratings is both weak and irregular, while at the same time the discharge from the front is injuriously affected.

At Harrietville these difficulties are overcome by a change in the design of the mortar box itself, and by using screens of different mesh. The two ends and the front of the mortar make a curve which is an arc of which the straight line of the back of the mortar is the chord. The discharge surface is subdivided into three equal portions, each 2 feet long. The splash at the ends being weaker than in front the former have gratings pierced with 175 holes per square inch, while the latter is provided with a grating carrying 240 holes.

While the mortars used at Harrietville are well designed, nevertheless the writer does not wish to be understood as recommending the double-discharge mortar. The ore of the mine is easy to crush and the gold which it carries is readily amalgamated, therefore he is of the opinion that if the mill were equipped with rock-breakers and self-feeders of approved design, and if the mortars were of the simple single-front discharge kind, if the stamps were a little heavier and fell a little faster, that then the capacity of the mill would be very considerably increased without a decrease in the percentage of gold extracted out of the ore.

The concentrates from the percussion tables are roasted and amalgamated. The roaster is a simple reverberatory furnace. The hearth is 27 feet long and 9 feet wide. Its length is subdivided into three equal portions, each separated by a drop of 2 inches. The charge is 12 hundredweights. The

time taken is eight hours. The daily capacity of the furnace is four tons. Immediately below the roaster is the amalgamation plant, consisting of two Wheeler pans and one settler. The extraction of the gold is exceedingly good, ranging from 90 to 97 per cent. of the assay value of the concentrates.

The Harrietville mill is distinguished among Australian mills in that the work done is checked by regular and systematic assays. A sample of the tailings is taken every hour, the resulting pulp being assayed each day. This is a feature of the methods of management worthy of unqualified praise; it is a portion of mill work only too rarely attended to, with the consequent loss of gold due to bad milling which is the direct result of the ignorance of the millman as to what he is really doing.

The extraction of the gold in the ores treated by this mill is particularly good, the tailings containing often as low as five grains per ton. In the actual results obtained and in the systematic methods employed, this plant reflects much credit upon the local English management.

Referring to the comparative table given in the earlier portion of this work, it will be seen that the other four mills whose figures are given have a general similarity in their methods. It will not be necessary to describe more than one of them, and the one chosen will be the Oriental mill, at Wandiligong, situated at the foot of the range which divides the Ovens River from one of its affluents. This mill is old and is a type of many of the small "crushing machines" which are scattered among the valleys of the Australian Alps. The two sections of the mill, each containing eight stamps, are separated by the overshot waterwheel, 27 feet in diameter, having a 3½ feet breast. Each stamp weighs 7 hundredweights. The ore is broken at the mines, any large lumps arriving at the mill being subjected to sledge-hammer treatment. There is no rock-breaker. The ore-bins are, however, supplied with self-feeders of a simple but effective type.

The tappet of the stamp strikes a rod which communicates the shock to the chute leading from the ore-bin. The hand screws enable the millman to increase or decrease the angle of the chute, according as the ore is coarse or fine, wet or dry. This feeder costs £8 and works well.

The stamps have a drop of 9 inches. When new dies have been placed in position the depth of discharge is 2 inches. The stamper box or mortar is 6 inches deep, while the die or false bottom is 4 inches deep. The maximum depth of discharge would be 4 to 4½ inches. The speed of the mill is regulated at a rate of from 55 to 60 drops per minute. The crushing capacity is 120 tons per week of six working days. The grating or screen is of round-punched Russia iron, having 220 holes per square inch. The pyrite in the ore is not saved, but in place of concentration the tailings are treated in Wheeler pans. The amalgam retorts 52 per cent., varying from 40 to 60 per cent. The bullion is worth £4 per ounce, equal to a fineness of .940.

The gold saving is done by the mortar box, by wells, by amalgamating tables, and finally by pans outside the mill itself. Mercury is added to the ore fed into the battery, and the mortar thereby becomes an amalgamating machine. With ore containing an ounce per ton a pellet of mercury of the size of a pea is added every two hours.

The amalgamating tables are covered with plates of plain copper. They have a total length of 15 feet and are subdivided into four sections, the first being 3 feet and the others 4 feet each. At the bottom of the first length of plate, sometimes called the "apron," there is a well 6 inches deep, while at the bottom of the next two divisions there is in each case a well 4 inches deep. Each plate is further subdivided by a shallow well or ripple which crosses it half way down. This is 3 inches wide and three-eighths inch deep. There are thus altogether three wells and four ripples.

Of the total amount of amalgam saved, 2 per cent. is caught in the wells, most of it in the first one, 48 per cent. comes from the amalgamating tables, and the remainder from the inside of the mortar box.

The tables have a fall of three-fourths inch per foot. This is slightly under the average of Australian mills and necessitates the use of an increased amount of water. The passage of the pulp over the amalgamated surface is slow, and this fact forms a good feature of the arrangement, but on the other hand a very nice adjustment of the supply of water is demanded.

In certain cases, where customers so desire, a copper plate 12 inches wide by 15 inches broad is attached to the "splash-board" immediately outside and facing the grating. It receives the splash of the pulp as it issues from the battery, and is placed at such an angle that the pulp will just not pass over the upper edge, but take an up-and-down wave movement over its amalgamated surface. It is a very efficient aid in collecting the gold.

As a rule only the first length—3 feet—of copper is used on the tables. Frequently customers place plates of their own over the remaining length.

The blanket strakes below the tables are 12 feet long, with a gradient of 1¼ inches per foot. They are not often brought into use.

The tailings pass outside the main building and are conducted to a tailings mill, shortly to be described. Contrary to the usual Victorian practice wooden guides are in use. The wood obtainable in the immediate neighborhood is very suitable for this purpose. The millman* informed me that a set of top guides made of red gum (*eucalyptus rostrata*) has lasted for 16 years. The lower set does not wear so well, since it is splashed by the water from the battery and injured by the accompanying grit. Iron guides are found to require ten times as much grease for their lubrication.

The shoes and dies are both made of wrought iron. The latter wear down very evenly and can be used until very thin. The shoes do not give such good service on account of the softness of the material, which is not well adapted for the work to be done.

The tailings plant consists of two grinding pans and one amalgamating pan, the motive power required being derived from a waterwheel 24 feet diameter and 2 feet breast, operated by the tail-water of the upper millwheel. The grinding pans are each 5 feet in diameter and 19 inches deep. They make 40 to 45 revolutions per minute. The pulp then passes to an amalgamator or amalgamating pan 6 feet in diameter and 22 inches deep. This makes only 15 revolutions per minute. All the pans are of the Wheeler pattern. The

* Mr. Chas. Fraser, to whom I am indebted for much information.

second grinding pan is generally used as an amalgamator, and the pan intended particularly for amalgamation is used as a settler. The capacity of this plant is 15 tons per week of six working days. Its cost, complete, with shed, was £524. Worked by water-power it requires no labor in addition to that employed in the mill. When the latter is idle, it necessitates an expenditure of £6 per week in wages. The wearing parts are renewed every six months and cost £20 per double set.

By referring to the comparative table, given in the earlier portion of this paper, it will be seen that the mills have a general similarity in their methods. The principles of the milling practice of this district were derived from the experience of Clunes. Clunes has been to the Colonies what Gilpin County is to the Western States; its methods are not necessarily the best, but it has been a school wherein the bed-rock principles of milling have been more thoroughly learned than has been the case in localities where mills are more new, more costly, and better arranged. The mills of the Ovens district do not fulfill the millman's ideal. Most of them are old and in want of repair; those which are new are incomplete, but the men in charge understand what they are doing, and there is reason to believe that as the mines of this Alpine region become developed the need of larger and better reduction plants will be fully recognized and their working will be in the hands of men, many of whom will be ready to adapt themselves to newer methods and altered conditions.

CHAPTER XI.

The Use of the Stamp Mill for Ores Unsuited for Such Treatment.

The Thames gold field was proclaimed upon July 28, 1867. This once famous mining district, also known by the Maori name of Hauraki, is situated on the northeastern coast of the north island of New Zealand. The earliest discoveries were of alluvial gold, but in August of the same year the first quartz reef was found in the bed of Kuranui Creek, where afterward was opened up the Shotover claim, famous in Colonial mining records. Though the output has now dwindled to about 30,000 ounces per annum, this has been in its day one of the richest gold fields of the world. In 1871 the output was 330,326 ounces, valued at £1,188,708. The Caledonia mine in the first twelve months' operations produced ten tons of gold and paid £600,000 in dividends. The Moanataeri, Manukau, Golden Crown, and others, similarly gave remarkable yields.

Though the mines have not yet attained any great depth, 600 to 700 feet being the maximum, the veins have proved to be far less rich than they were near the surface, and while the opening up of new districts has drawn away many of the best miners, the development of the gold field is also crippled by share jobbing. It is the story of many another mining camp, and like many other old districts the Thames is worthy of the further systematic development, more particularly near the surface, which its history invites.

Few mining districts have had so brief but brilliant a record, and few perhaps have lost such a large portion of the gold extracted from the mines. Milling is conducted under the difficulties presented by ores of very variable and very complex composition, but so far the efforts made to overcome

those difficulties have been of the most elementary kind. It is for this reason that the tailings mills are to-day* among the most profitable undertakings upon the field, and that the mining industry of the place is at a lower ebb than its history has ever known.

There are about 500 stamp heads and 350 Berdan pans at work in the district of Hauraki. The mills are without exception old and date 10 to 17 years back. The work done in them is most incomplete, since, notwithstanding the fact that the ore contains a large percentage of sulphides, there is no attempt made at concentration. Ordinary wet crushing is supplemented by the use of blankets, the washings from which are treated by pans, methods which do not prevent the tailings from carrying away a large percentage of the value of the ore. The tides in their ebb and flow are concentrating the material which they receive, and are giving a daily lesson to the careless millman, a lesson unappreciated by him, but readily understood by the proprietors of the tailings plants who are making money by the treatment of the sands.

Briefly stated, the method of milling consists in catching all the "free gold"—that is, all the gold which can be arrested by means so simple as to be quite unsuited to the character of the ore, and allowing the remainder to go to enrich the sea beaches. The character of the ore and the lode formation in which it occurs partially help to explain a state of things which calls for such severe criticism. The bulk of the gold comes from narrow veins and extremely rich pockets traversing a decomposed andesite. The ore bodies of such a formation must necessarily be uncertain in behavior and limited in extent. Like the deposits of the Nagyag and Veraspotak mines of Transylvania, to which they have a striking resemblance,† the pockets found at the Thames are occasionally of extraordinary richness. Such was the lot of 2 tons 8 hundredweights, crushed by the Moanataeri in 1878, which yielded 14,000 ounces, or at the rate of 2½ ounces per pound. One bowlder of 2½ hundredweights yielded 3500 ounces. These crushings of small quantities of very rich ore pay the dividends and form a very large proportion of the value of

* Referring to the time of the writer's examinations in 1891.

† As they also have to those of Cripple Creek in Colorado.

the entire output. This is well illustrated by the returns obtained during six weeks in 1885 by the Cambria Mill.

		Amalgam. Ozs.	Bullion. Ozs.
First fortnight, November, 1885.	235 tons stone.	1524	535
	1400 lbs. specimen ore.	6088	2312
Second fortnight, November, 1885. . . .	393 tons stone.	2031	777
	1553 lbs. specimen ore.	4531	1802
First fortnight, December, 1885	236 tons stone.	1600	583
	1970 lbs. specimen ore.	8115	3229

The bulk of the output being thus of a value small in proportion to its weight when compared to that of a few sacks of "specimen ore," it is easily conceivable that it has not received the attention which it demanded.

The following comparative table of five of the principal mills will indicate the chief features of the milling:

COMPARATIVE TABLE.

Name of mill.*	Number of stamps.	Weight of stamps, pounds.	Number of drops per minute.	Height of drop, inches.	Average depth of discharge, inches.	Capacity per head, tons.	Capacity of mill, tons.	Descript'n of screen.	Number of holes per square inch.	Fineness of bullion per 1000.	Per cent. in retorting.	Life of the screen, days.	Loss of mercury, dwts. per ton of ore	Number of Berdans.	Number of other pans.
Saxon	32	785	72	9	2½	1.8	58	R'd p'ch Russia iron.	148	663	42	6	14.5	8	3
Moanataeri	40	659	66	8	2	1.4	55		170	641	40	6	15.2	21	4
Cambria	20	620	76	9	8	1.7	35		180	674	40	5	. .	15	. .
Kuranui	20	670	70	5½	2¼	2.5	50		160	605	45	5½	. .	7	. .
Comer	20	840	63	6	2½	3.6	72		160	589	48	5	. .	5	. .

It would be wearisome to describe each of these mills in turn, so I will choose the Saxon, which is perhaps the most representative.

The Saxon mill contains 32 stamps, which crush the ordinary ore, and one single stamp, which is kept for the treatment of the specimen ore. The plant bears evidence of its growth in the varying weight of the stamps, which is as follows:

Ten "light heads,"	in 2	batteries of	5	each	588	pounds.
Twelve "medium,"	in 2	"	6	"	644	"
Ten "heavy,"	in 2	"	5	"	784	"

The shoes and dies vary in similar proportion. The rate of drop averages 72 per minute, but this speed is subject to change. The height of the drop is from 8 to 11 inches, depending upon the hardness of the ore. The issue or depth

* No concentrates are obtained in any of these mills.

of discharge is about 1 inch at the time of putting new dies into position, and increases to a maximum of 4 inches as they are worn down. There is no attempt made to keep the depth of discharge constant.

The single stamp weighs 7 hundredweights, or 784 pounds. It is given a 7-inch drop and a speed of 60 drops per minute. This "specimen stamp" is a curious feature of all the mills.

The crushing capacity of the mill is from 30 to 35 loads per day. A load varies from 30 to 35 hundredweights. When not engaged in treating the specimen ore the single stamp assists the other 32 in the crushing of the general output of the mine.

The screen or grating used is of Russia iron, imported from Swansea. The openings are round punched and 148 per square inch. The life of a grating will average one week or six working days. (No work is done in the Colonies at mines or mills on Sunday.)

The loss or consumption of mercury is at the rate of one bottle (of 75 pounds) per month, there being three bottles in use in the mill at any given time. No mercury is used in the mortar boxes, save in the case of the specimen stamp; it is employed, however, on the plates outside, in some of the "ripples" or wells, and in the pans. Owing to the "flouring" produced by the pans the loss of mercury is excessive, being 14½ pennyweights per ton of ore treated.

Forty-two per cent. of bullion is obtained in retorting. A representative crushing* of 30 loads gave 479 ounces of amalgam, yielding 203 ounces of bullion.

We will now follow the ore through the different stages of the treatment. It is brought to the mill in carts and discharged into stalls or ore-bins behind the batteries. There is no rock-breaker in use, no grizzlies or sizing-bars, and the ore is hand fed. The feeding is badly done. The ore varies greatly in hardness, according to the extent to which the andesitic vein filling is decomposed. The quartz itself is often sugary and crystalline. The shoes and dies, both of local manufacture, are made of white hematite cast iron, that of the die differing from that of the shoe in being unchilled. The shoe is 9½ inches in diameter and 10 inches high. The

*This was in April, 1891.

die is 10 inches diameter and 4 inches deep. The die is cast with a flange so as to keep it in position.

The mortar boxes are faulty in design since they are too roomy; there is unnecessary space in and around the dies, seeing that no amalgamation takes place inside. The pulp is discharged upon amalgamating tables 7 feet long and 4½ feet wide. These are in three divisions, of which the upper two only are lined with plates. The first length is 2½ feet, inclusive of a well 2½ inches wide. This well contains mercury. The next length of table is 18 inches. The "ripples" or riffles, as they are called in the United States, are four in number, one only, that already mentioned, containing mercury. The other three are "blind ripples." They are 2 inches deep.

The gold saving is effected by amalgamated plates, by wells, and indirectly by blanket strakes, whose residues are treated in pans. There is no concentration in the ordinary sense of the term.

The mortar box is not a gold-saving appliance, but merely a crusher. The first amalgamation takes place on the outside plates. These are made not of copper, but of Muntz metal. They are roughly cleaned up every 4 hours. The wells are of very little assistance; wells *per se* are unsuited to ores containing a notable proportion of sulphides. The surface of the bath of mercury is continually coated with a scum of sulphides, which prevents contact with the gold in the pulp passing over it. Here the wells are skimmed with a cloth every 4 hours. The mercury placed in them is squeezed once per week. The six wells (one to each battery) in the mill catch about 12 ounces of amalgam out of the weekly yield for the entire mill of 200 to 250 ounces.

The "blind ripples" are not true wells, since they hold no mercury. They are cleaned with a scoop every half hour, the heavy sand and sulphides so obtained going to the pans.

The blankets are washed every hour, this interval varying, however, according to the richness of the ore and the amount of sulphides which it contains. The washing of the blankets is done by one boy on each shift, three boys per day, each of them paid £1 per week. The blanketings go to the pans. Of these there are three varieties.

The Berdans and one Watson & Denny treat the blanketings. The other two are working tailings. The Berdans have a pitch of 16 inches in 3 feet 6 inches, or 1 in 2⅝. The speed is regulated at 23 revolutions per minute. The amalgam is removed every 24 hours. Instead of a ball, a drag is used. It consists of two parts, the "slipper" or shoe weighing 196 pounds and the top or boss 233 pounds. They are held together by a key, and the surface of contact between the two parts is lined with cement. The shoe lasts about 4½ months.

NUMBER AND DIMENSIONS OF PANS.

	Diameter.	Depth.
Eight Berdans.	4 feet 6 inches.	9 inches.
Two Watson & Denny . . .	5 feet 4 inches.	2 feet 6 inches.
One Price (local)	5 feet 8 inches.	2 feet 7 inches.

The distribution of amalgam, which also indicates the proportion of gold saved by the various parts of the mill, is as follows: At the fortnightly clean-up, preceding my examination of the mill, 200 ounces 4 pennyweights of melted bullion were obtained from a retort of 203 ounces, which was the yield from 476 ounces of amalgam, which last was thus distributed: Plates, 223 ounces; mercury wells, 24 ounces; pans, 43¾ ounces; 35 pounds of specimen ore, 164 ounces.

The balance is made up by the skimmings, etc. The amalgam obtained from the picked stone is obtained in the mortar box of the "specimen" stamp. Mercury is always added to the coffer or mortar box of the single stamp, and all the tailings are saved for retreatment in the Berdans. The power for the machinery comes from two Pelton wheels, one 5½ feet in diameter, which drives the stamps, and one 3½ feet in diameter for the pans. The water from the small wheel is used in the batteries. The cost of water under 60 pounds pressure is £3 per sluice head (50 cubic feet per minute) per week. It amounts to £36 per month. A small dynamo generates the electricity which illuminates the mill at night. The ore treated gives an average yield of 15 pennyweights per long ton.

The following figures will indicate the cost of the mill treatment at the Saxon mill per 24 hours with 33 stamps crushing 63 tons. This includes the "specimen" stamp; 3 feeders at 6s. 8d. per shift of 8 hours, £1; 3 boys, feeders also, at 5s.,

15s.; 3 blanket boys at 3s. 4d., 10s.; 3 amalgamators at 8s., £1 4s.; total labor in 24 hours, £3 9s. One of the amalgamators is the superintendent or manager of the mill. The cost of labor is, therefore, 1s. 1d. per ton, while the total cost, including power, supplies, wear and tear, alterations to machinery, interest on capital, etc., is 4s. 1d. per ton. At the Moanataeri mill, which is a larger plant, the cost is 3s. 9d. per ton.

Coming to the examination of the comparative table it will be noted that the mills are for the most part small, being in this respect proportioned to the size of the mines. The Moanataeri mine has the most extensive workings, and owns a comparatively large mill. The weight of the stamps varies from 620 to 840 pounds. The speed varies within narrow limits only—from 63 to 76 drops per minute. In the height of the drop there is a greater disparity; the first three mills are treating ore which comes from depths varying between 200 and 500 feet from the surface, and the drop is from 8 to 9 inches, but the last two are treating soft surface material, which fact explains the comparatively low drop of from 5 to 6 inches. The depth of discharge or issue—the distance from the top of the die to the bottom of the screen or grating—in all the mills is regulated by the wearing down of the dies. It varies from nil with new dies to a maximum of 5 inches, and will average from 2½ to 3 inches. The importance of having a depth of discharge suited to the particular mode of working aimed at and the particular ore treated is a point quite unappreciated. It is curious to note that in most districts the importance of this feature of the milling is, as a general rule, overlooked.

The crushing capacity varies but little for the first three mills, from 1½ to 3¾ long tons per stamp per 24 hours being the average. At the Moanataeri it is lower than at the Cambria or Saxon, by reason of a shorter drop. The Cambria crushes fast in proportion to the weight of the stamps; this is due to the fact that it is a custom mill or "public battery." The slightly deeper discharge is more than made up for by the quicker drop. The Kuranui Hill mills—Hansen's and Comer's—put through a much larger quantity, since they crush soft surface material of low grade.

The gratings or screens are all made of round-punched

Russia iron, imported from Swansea. The fineness varies from 148 to 180 holes per square inch. The shorter life of the screens in the mills treating surface ore, notwithstanding the lesser hardness of the material which passes through them, is due to the presence of the acid sulphates, derived from the oxidation of sulphides, which, by the reactions induced, corrode the iron of the grating. Owing to the greater speed of crushing, however, the gratings in Comer's mill, for instance, last during the passage through them of 90 tons (long) as against 54 tons at the Saxon. The result compares badly with that of other districts, and is due to the direct action of the acid mine waters, as well as to the more indirect reactions induced by those waters, when in the battery, upon the partially decomposed metallic sulphides. It may be mentioned here that the chemical reactions produced by the underground waters in the mines of this district are so marked as to suggest the effects of a slowly dying solfataric agency.

The loss or consumption of mercury does not vary much, and is represented by one bottle (75 pounds avoirdupois) per month for 30 stamps. It is a high consumption, and is due to the flouring of the mercury by the grinding of the pans, as well as to the evil effects ("sickening") produced by the presence in the pulp of antimonial and arsenical minerals.

The bullion is of low grade, having a fineness which ranges from .589 to .674 per thousand. At the Moanataeri and Saxon it varies as follows: Saxon, gold .6523, silver .341; gold .6744, silver .316. Moanataeri, gold .638, silver .342; gold .6419, silver .343; gold .6432, silver .349.

Before venturing upon a further criticism of the methods of treatment, it will be well to give a general description of the character of the ore. The lodes from which it is obtained are small and not very regular veins, which traverse a hornblende andesite which is often brecciated. The lode formation is confined to certain belts marked by the decomposition of the country rock. The millstuff consists of a large proportion of the country rock, which has a hardness varying according to the degree of its decomposition. The ore is silver-bearing as well as gold-bearing. The gangue is largely quartz, which is arranged in veinlets and stringers through the country rock included within the limits of the vein. Sometimes

the quartz is soft and sugary. While the gold is frequently visible in the quartz in the form of minute threads and particles, it is also largely associated with copper and iron pyrites, blende, galena, etc. It occurs coated by native arsenic. Silver occurs in various forms, such as pyrargyrite, proustite, argentite, etc. The two precious metals are found associated with tellurium, as petzite and sylvanite. Selenides are known to exist in the ore. Antimony in beautiful crystals of stibnite is often seen.

Generally speaking, the ore has a varying hardness and composition; it contains a large variety of metallic sulphides, and must be considered both a silver and gold ore. Containing from one-half to 10 per cent. of sulphides, with an average of from 2 to 3 per cent., it approaches the boundary line which divides a "free-milling" from a "refractory" ore.

An endeavor will now be made to pass in review the chief characteristics of the milling.

In none of the mills is there a rock-breaker; therefore there are also no grizzlies or sizing screens. In every case the feeding is done by hand, and in most cases done badly. The feeding is very rough. Instead of using trained men for this important work, it is left to boys who shirk the breaking of the big pieces of the rock, preferring to throw them into the feed-opening of the mortar box, where, if they stick, they are rammed in with a few blows from the sledge hammer. The results due to the absence of rock-breakers and automatic feeders, coupled with the bad hand-feeding which obtains in the mills, is seen in the excessive wear and tear of the shoes and dies. The average wear is at the rate of 22 ounces of iron per ton of ore crushed—14.5 ounces for the shoe and 7.5 ounces for the die.

The feeding, while it is irregular, is also too high. The batteries are kept almost choked up with ore, so that the stamps do ineffective work.

The mortar boxes are all of the same pattern, whether employed for the rapid crushing of soft material or the slower treatment of the average ore. Seeing that no amalgamation is attempted inside, they are too wide. When the battery is simply a pulverizer the pulp should be expelled from the mortar as soon as it has been reduced to the size required;

with an unnecessarily roomy mortar the pulp lingers after it has been reduced to a fineness which will allow of its passage through the grating. When amalgamation takes place inside this serves a purpose, but at the Thames it only permits of that unnecessary sliming of the ore which causes a heavy loss of fine particles of gold. Narrower mortars are, therefore, advisable.

The gratings are all of one description. As already pointed out, the wear is much affected by the character of the ore. Material which has lain for some time in the stopes or waste from surface destroys the iron of the gratings by reason of the sulphuric acid produced by the decomposition of the sulphides. The mine waters contain an unusual quantity of the protosulphates of iron, copper, manganese and alumina, and, as a consequence, when the millstuff is very wet the action upon the gratings is very marked. As is usual in the Colonial mills, the screens are arranged vertically instead of having a slight forward inclination. This tends to wear the lower portion much faster than the upper. The amalgamating plates are made variously of copper and Muntz metal. At the Saxon and Kuranui mills Muntz alone is used; at the Moanataeri plain copper, but at the Cambria and Comer both are used. In the former the top portion of the plates or tables is Muntz, and the lower part copper; in the latter it is *vice versa*. The use of Muntz metal will be fully discussed later on.

As already pointed out, the wells serve but little purpose, since they are not of the type (known as drop wells) that compels the pulp to pass through the body of the mercury bath. The small amount of gold which is collected by them only confirms the general experience that with ores containing an appreciable percentage of sulphides ordinary mercury wells are rendered comparatively inoperative by the formation of a scum over the surface of the bath. The "blind ripples" are still more useless, since they serve no particular purpose, either as arresting free gold or collecting sulphides. The amount of attention which is given to them is out of proportion to the quantity of sulphides and heavy sand which they collect.

The blankets at most of the mills are washed at intervals which are too long. Tributers or lessees understand this, for

when putting through a lot of ore at any of the custom mills, they themselves attend to this part of the work. In such cases they will usually wash the blankets and skim the wells every half hour. The blankets cost 12 shillings per yard of two yards wide. They are manufactured particularly for mill use at Mosgeil, near Dunedin, in the south island. They last for three months.

The Berdan pans have a good feature—that is, the use of a drag in place of a ball. It is a step in the right direction. The ball always remains in the lowest portion of the pan; the mercury also collects there, and, as a consequence, the latter is ground by the former, with the formation of "floured" mercury, which escapes with the slimes. The drag, which is fixed to one side of the pan, keeps the work of grinding apart from that of amalgamation.

The concentration of the rich sulphide minerals is unattempted save by blankets, and in rare cases by such a rude method as "tyes." An attempt was made to encourage this portion of the milling, and a Newberry-Vautin chlorination plant was erected at the Thames, but owing to the impossibility of obtaining a regular supply of concentrates the works had to be shut down.

In summarizing the treatment which the ore undergoes at the mills, it is not too much to say that it is very crude and incomplete; it succeeds in arresting only that portion of the gold which is readily amalgamated, and fails entirely in saving the silver contents. The silver in the bullion is not the result of amalgamation with the silver in the millstuff, for the proportion of silver to gold in the bullion is that of the native gold of the district, which, like that of the Transylvania gold field, is of very low caratage. On the most favorable estimate the treatment cannot be said to be even half carried out, for scarce 50 per cent. of the gold is extracted, leaving out of account the silver. The waste of many of the mills will assay about half an ounce. Much of the gold, and nearly all the silver, is carried out in the slimes, which, being deposited along the foreshore, have produced an accumulation of tailings estimated to amount to at least a million tons, carrying half an ounce of bullion per ton. That this is not an exaggerated statement is proved by the success of the tailings mills.

These are engaged in the treatment of both the old accumulations and the "waste" now being sent down. It is a sufficiently severe condemnation of the work done at the Thames to state the fact that the tailings mills, using the same methods of extraction as the mills themselves (that is pans, not even preceded by finer crushing), are enabled to pay well. It is a sorry fact to have to record that even after this second treatment the tailings still contain a notable amount of gold and silver.

The largest of these plants to treat the tailings contains 12 Watson & Denny pans. The tailings are elevated and conveyed by water. This is very effectively and simply done by a small hydraulic elevator. The jet is five-eighths inch diameter, the supply or pressure pipe 2½ inches, and the elevator or discharge pipe 3 inches. The water used is under a pressure of only 60 pounds per square inch. The launder from the upper end of the elevator pipe conveys the tailings to wide strakes or buddles, where the poor slime is washed away and the rough stones picked out before feeding the material into the hopper of the pans. A handsome profit is being obtained. The total cost per ton—including insurance, interest on plant, wear and tear, etc.—amounts to 3s. 6d. per ton.

But what is the remedy? may naturally be asked after such a severe condemnation of existing methods. First, to point out one vital error in the treatment. No reference is here intended to the fact that the rich silver-bearing minerals are allowed to go out to sea without any attempt at saving or concentrating them—that is no error, but pure carelessness. While blanket strakes, followed by pans, form a process which is quite ineffectual as regards the saving of the silver contents of the ore, it is also badly suited to the extraction of any free gold remaining in the pulp after its passage over the plates. The grinding action of the pans upon the sulphides forms slimes, which, sickening the mercury, causes its direct loss as well as spoiling its power of catching the gold by amalgamation. To make the pan treatment successful the previous roasting of the sulphides is necessary.

The ore is both silver- and gold-bearing; the former is chiefly associated with the sulphides, the latter occurs mainly in the quartz, while both metals occur combined as tellurides

etc. Some separation is, therefore, needed between the silver-bearing and the gold-bearing portions of the ore. The tellurides, etc., would be saved in the same operation as the former. It is suggested, therefore, that from the plates the pulp should pass direct, discarding the blankets, to concentrators and thence to the pans. The concentrators would separate out the silver-bearing sulphides and some of the combined gold, and the pulp freed from the sulphides would go to the pans, which would complete the extraction of any free gold remaining.

This is a very obvious improvement on the present treatment. It is the so-called "combination" process. It is not necessary to erect an expensive plant of concentrators; it will answer well enough to commence with some simple form of shaking table, and of this type of machine there are various forms to choose from, among which may be mentioned the shaking table of the Colorado mills, or that extensively used in Victoria—both simple and inexpensive.

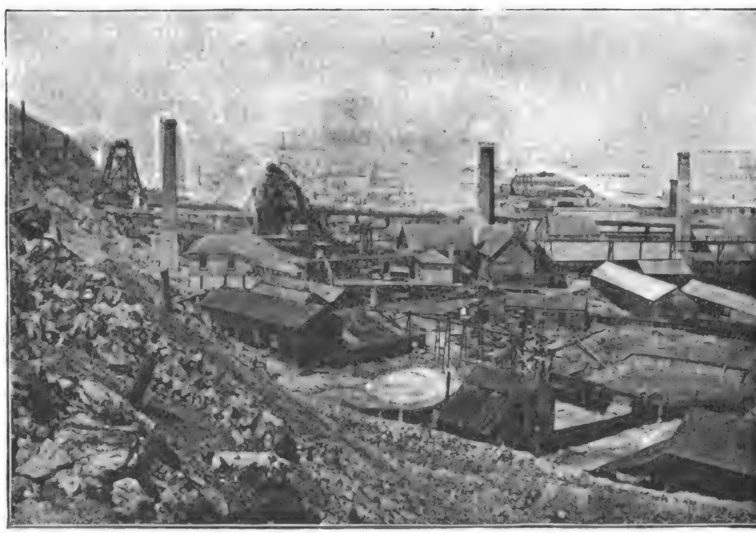
The process would be made more correct and the work of the concentrators much lightened by the intervention of classifiers between the amalgamating tables and the concentrators. Spitzlutten or water-jet classifiers would be most simple, inexpensive, and complete machines for this purpose.

The treatment above suggested would not interfere with the present amalgamation upon the tables; it would be supplementary. The initial cost of such an addition would be small, and as the machines are practically automatic the additional cost of treatment would be extremely small.

As to the handling of the concentrates, their after-treatment, that need not concern us here as it is outside the scope of stamp milling proper. It is to be determined by careful experiment whether chlorination, cyanidation, or matte smelting is the most practicable.

The mills of this district offer one point of particular interest, namely, the use of Muntz metal on the amalgamating tables. The composition of Muntz metal is 60 per cent. copper and 40 per cent. zinc. Its first introduction into mill use took place in 1875. At that time copper plates were not obtainable in sufficient quantity, and the Thames being a seaport the local ironmongers, who imported Muntz for the pur-

pose of sheathing vessels' bottoms, sold it in place of the copper. The first trials were very satisfactory, its use spread, and it has now largely replaced the simpler metal. Sheets of proper dimensions for mill use have not been introduced; those employed at present are generally of insufficient size, and require patching together so as to fit the width of the tables. The sheets used are also too thin for the purpose, being of the thickness known as No. 18. They last, however, from three to five years.



Mills in the Thames District.

Silver-plated copper is not used in the mills of this district, hence the comparisons to be made will be confined in this instance to Muntz metal and plain copper. In many respects the facts noted will apply also to the better class of amalgamating plates.

Muntz metal, as used for amalgamation, has the following characteristics. It does not absorb amalgam like copper. The latter has to be well coated with gold amalgam before it does any good work, and in a new mill it is always advisable to allow the copper to become thoroughly amalgamated before the plates are cleaned. Muntz metal has very little absorbing power over the mercury—that is, the amalgamation is, as

compared to that of copper, very superficial. In practice several results follow. First, the clean-up is much facilitated, for the amalgam formed on the Muntz is very readily detached, not requiring the more laborious cleaning up demanded by copper plates. A steel tool is never used, rubber being always sufficient. Secondly, test crushings are more reliable. Gold will not collect upon a poor copper plate as it will upon a rich one, so that in practice the yield from a lot of ore will be much affected by that of the previous lot. It is not possible to scrape a copper plate closely without injuring its amalgamating capabilities. It is not so with Muntz metal, which can be readily deprived of its previous gain of gold amalgam without impairing its efficiency. It is, therefore, particularly suited to custom mills.

On the other hand, for very rich ore Muntz is not advisable, for "there is no body in it," as the Thames millmen say—that is, it is sooner saturated with gold amalgam than is the copper. In the same way silver-plated copper will carry more amalgam than the plain copper. This is a disadvantage to be partially overcome by frequent cleaning up, a remedy, however, which does not get over the defect.

When ores contain minerals injurious to the mercury Muntz metal is preferable. It is noted that in the presence of base minerals "sickening" of the mercury does not occur as with copper plates. The explanation is to be found in the zinc, of which it is partly composed, which, by reason of a feeble galvanic action which is set up between it and the copper, electrolizes the water and liberates the hydrogen, which, being in a nascent state, exerts a powerful reducing effect, somewhat after the way of the so-called "hydrogen-amalgam" process. In practice there results the fact that Muntz metal plates are easier to keep in good order than the copper. When the millstuff contains a notable percentage of the heavy sulphides, particularly such as are directly injurious to amalgamation and "sicken" the mercury, it is seen that the Muntz is hardly affected. The "verdigris" of the millmen is not formed upon Muntz metal plates. At the Saxon mill it required over a jar (7 pounds, costing 23 shillings) of potassium cyanide to dress the copper plates, and so keep them in order; it was found upon introducing Muntz metal that half a bottle

(one bottle costing 6s. 8d.) of sulphuric acid would suffice during the same length of time, viz, one month.

On the other hand, it is known that for highly acid ores, such as certain heaps of waste ("mullock tips" or dumps), which contain much sulphuric acid, resulting from the oxidation of pyrites, the copper is to be preferred. Under such conditions a heavy scum is formed upon the Muntz, while the acid tends to keep the copper clean

At the Cambria, which is a custom mill, both varieties of plates are used, Muntz for the top and copper for the lower portion of the tables. This is done to meet the requirements of different classes of ore. At the Comer mill the arrangement is reversed, the top plate being of copper.

The result of the experience of the Thames mills has been, therefore, to recommend the use of Muntz metal for amalgamating plates where poor ore is being crushed, also in custom milling and where the ore is charged with minerals which injuriously affect the mercury. For material containing acid waters or for very rich ore, unaccompanied by a large percentage of sulphurets, copper is to be preferred.

In general it may be added further that Muntz metal is the cheaper of the two; it lasts longer and requires less attention.

It would be well to try Muntz metal in other districts where somewhat similar conditions obtain. It possesses two certain advantages: it wears better than the ordinary plates and it facilitates a rapid and complete clean-up. This should recommend it to custom mills. Its other advantages must depend upon the character of the particular ore whose gold contents it is called upon to amalgamate.

In dressing new Muntz metal plates the following are the steps to be taken: Rub the surface of the new plate with fine clean sand to get it mechanically clean, then wash it with a weak (1 to 6) solution of sulphuric acid to make it chemically clean. Then start to rub in a little mercury, rub in one place "until it bites"—that is, the plate becomes amalgamated. Give a circular movement to the flannel or mop. Once started the amalgamation spreads in ever-widening circles.

Every mining district has a lesson to give, every mill some suggestion to offer; in the case of the Thames the point of most interest is undoubtedly that which we have last considered.

Since the above was written I have received an account of a trial crushing made at one of the mills of the Thames. The milling practice of this district has been described, the methods employed have been very severely criticised, and the mills condemned as totally unsuited to the reduction of the ores whose values they were intended to extract. In estimating the percentage of the saving, I stated that "the treatment cannot be said to be even half carried out, for scarce 50 per cent. of the gold is extracted, leaving out of account the silver." From the columns of the local newspaper I learn that the Director of the Government School of Mines has been investigating the question, and that recently a test mill run was carried out at a representative mill (the Cambria), which is under the charge of Mr. T. A. Dunlap, certainly one of the most experienced of the local mine managers.

The results indicate that my criticisms were fully warranted. Twenty-seven tons of ore were crushed. Each ton contained 7 ozs. 18 dwts. 19 grs. of gold, and 9 ozs. 14 dwts. 2 grs. of silver, worth, together, £333 4s. 6d. The extraction was as follows: From amalgamating plates, £30 0s. 7d., or 3.3 per cent.; from pans (Berdans), £432 15s. 5d., or 48.2 per cent.; total, £462 16s. 0d., or 51.5 per cent.

It will be remembered that such concentration as is effected in the mills of this district is accomplished by the use of blankets, the washings from which are subsequently treated in pans. The account goes on to say: "Considering the highly mineralized and refractory character of the Alburnia ore, the percentages of saving effected at the Cambria battery are remarkably high, and must be the result of much skillful manipulation; nevertheless, it seems a pity to see so large a loss of bullion after the time and expenditure incurred in finding, mining, and carting the ore."

The "skillful manipulation" is sadly misdirected, and the "loss of bullion" is a woeful result, due to a follow-my-neighbor policy. The great axiom of successful milling is to adapt the reduction process to the character of the ore treated. This is the reason of the "variations" in the milling of gold ores. The Thames affords an instance of the disregard of this elementary law.

CHAPTER XII.

THE STAMP MILLS OF OTAGO, NEW ZEALAND.

The province of Otago, in the south island, was the first gold-mining district opened up in New Zealand. Its history dates from the discovery in June, 1861, of the golden gravel which made Gabriel's Gully a household word in the Colonies. It has ever since continued to be more of a rich and extensive alluvial field than a quartz-mining country, but the last few years have seen considerable progress in the development of the quartz lodes whose importance is becoming better recognized. Up to March, 1892, Otago, which has an area of 20,000 square miles, has produced 4,889,563 ounces of gold, having a value of £19,310,707, or $96,553,535. For the year ended March 31, 1892, the yield amounted to 105,531 ounces, worth £423,527, or $2,117,635.

The milling practice has largely followed that of the older mining centers of Victoria, but altered conditions have induced some variations which have given it certain characteristics which merit our attention. The three mills whose figures are given in the comparative table which follows are fairly typical. The Phœnix battery at Skippers is one of the best known in New Zealand, and nestles at the foot of the snowy ranges of the Southern Alps. The Premier at Macetown is an old mill shortly to be replaced by a larger plant. The last on the list is a mill at Nenthorn, a mining camp which, though of comparatively recent origin, has already passed through many vicissitudes of alternating failure and prosperity.

The Phœnix mill, at the head of the Shotover River, was one of the pioneers in the utilization of electricity for the transmission of power. The plant was erected in 1884, and

consists of two Pelton wheels under a head of 180 feet, which drive two Brush dynamos connected by two No. 8 B. W. G. copper wires, nearly three miles long, to a Victoria motor, which in turn supplies the power to run 30 stamps, together with a rock-breaker, and to light the buildings.

COMPARATIVE TABLE.

Name of mill.	Stamps.	Weight, pounds.	Drops per minute.	Height, inches.	Depth of discharge, inches.	Capacity of stamp, tons.	Capacity of mill, tons.	Grating.	Holes per square inch.	Concentrates, per cent.	Bullion per 1000.	Retort per cent.	Wear of gratings, days.	Loss of mercury per ton of ore, dwts.	Consumption of water, gallons.
Phœnix	30	800	78	7½	3½	1.4	40	Steel cloth	140	Not saved.	930	45	6	8.4	4
Premier	10	750	77	7	6½	1.2	12	*	180		949	34	8	7	3½
Reliance	10	850	75	7½	2½	2.0	20	*	200		850	35	12	5	5

Each stamp complete weighs 800 pounds. The speed varies from 75 to 80 drops per minute. The height of the drop is from 7 to 8 inches. The depth of discharge is variable. At the commencement of the month and immediately after the clean-up, it is 2½ inches. The maximum distance from the bottom of the grating or screen to the die or false bottom is reached when the dies are worn down and it is then 4½ inches. The average is therefore 3½ inches. The mill crushes 460 tons per fortnight of twelve working days, or at the rate of a little under 1½ tons per stamp per 24 hours. Two kinds of gratings or screens are in use. Wire cloth is chiefly employed, but when the supply runs short the ordinary round-punched Russia iron is substituted. The holes in the two cases are of similar size, but the number of them per square inch is 324 in the one case and only 140 in the other. The pyrite which the ore contains has been proved to be of very low grade and no after-concentration is therefore attempted. The bullion is 930 fine. The last two shipments, previous to my visit, were: .922½ fine, worth £3 18s. 3d., and .933 fine, worth £3 18s. 3d. The loss or consumption of mercury was 90 pounds avoirdupois during the crushing of 3107 tons of ore, being at the rate of 8.4 pennyweights troy.

* Round-punched Russia iron.

Automatic feeder

The gold saving is done by the mortar box and by blanket tables, the residues from the one and the washings from the other both undergoing supplementary treatment in an amalgamating barrel. The method of milling is particularly simple. The ore passes through a rock-breaker and is fed by an automatic arrangement into the battery. The feeder, though a very elementary contrivance, does very good work and is worthy of description. When there is insufficient ore on the die the tappet strikes the head of an iron rod whose lower end is fastened to a chute leading to the ore-bin. The bottom of the chute passes upward under the ore and the shock communicated by the stamp through the tappet to the ore causes it to move downward into the feed-hole of the battery. This is the idea which underlies most of the more complicated machines which are used for the same purpose.

The mortar box has a depth from the lip or level of discharge of 9½ inches, distributed as follows: Distance from bottom of grating to top of die, 2½ inches; thickness of die, 4 inches; false bottom 3 inches. This false bottom consists of two sets of four bars, which are placed under the dies and are packed in between with sand. Each of these bars is 3 inches square and has a length of 2 feet and 5 inches. The space between each bar and the distance of the outer ones from the side of the coffer or mortar box is in each case 3½ inches, the interior width of the coffer being 15½ inches. The whole arrangement is simply an expedient for surmounting the difficulties presented by a mortar whose shape is unsuited to the nature of the milling required by the ore. Before starting the mill the coarse sand from the previous clean-up is packed between and around the dies. The order of the drop of the stamps is 3, 5, 1, 4, 2. No mercury is added to the ore when in the mortar box, the gold being arrested by the action of gravity alone.

On leaving the mortar box the pulp has three drops, making 18 inches in all, before it reaches the uppermost blanket. This fall serves the purpose only of spreading the material. There are no amalgamating tables, and the pulp passes immediately over the blanket strakes. These last have a length of 18 feet and a width of 6 feet, subdivided into four partitions. The gradient is seven-eighths inch per foot. The quantity of

water used amounts to about four American gallons per stamp per minute, and is supplied to each 15 stamps by two 1½-inch pipes under a head of 25 feet. The blankets are freed from the gold and heavy sand which they collect by being washed in a tub of water. A vigorous movement through the water is given to them. The top row (there are four rows) of blankets is washed every hour and the lower ones at longer intervals, depending very much upon the richness of the ore.

The blanketings, or residues from the washing, are removed from the tub when a certain amount has been accumulated, and are conveyed in buckets to a barrel, 5 feet by 4 feet, having a capacity of 120 gallons, equal to about one ton of blanket residues. In running 25 to 30 stamps with the average grade of ore—15 pennyweights—to the ton, the supply for a barrel is obtained each day. Warm water is not used, nor are pieces of iron introduced, as is often done in California, with the idea of assisting the grinding, but with the result of flouring the mercury. Experiments are being made with the use of bluestone. A full bottle* of mercury is added. The barrel turns at a speed of 20 revolutions per minute.

When the amalgamation is considered to be completed, usually after 24 hours, the material is emptied into a vat underneath from which it is slowly fed by a running stream of water to a shaking table of the Rittinger type, and having dimensions of 8 feet length and 2 feet width. Below the table there are a few pieces of copper plate, which, however, serve but little purpose. The collection of the amalgam from the contents of the barrel by the shaking table occupies from 2½ to 4 hours, depending upon the rate of feeding which again varies directly with the heaviness of the pulp. The material —amalgam, pyrites, heavy sand, etc.—thus roughly concentrated is placed in enameled iron buckets to be further washed by hand in a "dish" or pan. This latter utensil has the shape of the ordinary friend of the prospector, but it is of copper, and, its surface having become amalgamated by frequent use, it readily collects the amalgam.

On examining the tailings below the shaking table, the

* In Australia a bottle of mercury contains 75 pounds, and in America a flask holds 76½ pounds avoirdupois.

writer found that they contained a large amount of floured quicksilver. It will be noted by reference to the comparative table that a loss of 8.4 pennyweights of mercury per ton of ore crushed is there shown. This is more than the average, and is due undoubtedly to the excessive speed of the amalgamating barrel, whose 20 revolutions per minute should be diminished to about 14. At Clunes, in Victoria, the speed is 16 revolutions with a much smaller barrel. At the monthly clean-up the battery residues are roughly screened on a riddle, and the larger bits of quartz removed previous to adding the remainder to the blanket washings, to share with them the treatment in the barrel.

Before entering into a discussion as to the effectiveness of the milling, the following additional details will be of value: Two kinds of screens or gratings are used—wire cloth and round-punched Russia iron. The friable quartzose character of the millstuff makes the former preferable. It is easier placed in position upon the screen frame, it has a somewhat longer time of wear, and a much greater area of discharge. The punched iron gives finer crushing at first, before the burr is worn off, but afterward becomes easily choked up. The short life of the gratings—a week for the wire, and slightly less for the punched iron—is not due to anything in the ore itself, which is a comparatively clean quartz, but to the fragments of wood (from mine timbers) which to a more than usual extent find their way into the millstuff. They choke up the gratings, which by reason of the pressure of the water and pulp thus held back are caused to burst. This is notably the case with the punched iron, which discloses lines of weakness along the vertical divisions made by the press employed in their manufacture.

The wire cloth, No. 18 mesh, costs 9 shillings per yard. It is sold in pieces 30 yards long by 2 yards wide. The grating cut out of this is 2 feet 6 inches by 10 inches. On the other hand, 120 punched Russia iron gratings cost £17, or 2s. 10d. apiece, as against 2s. 2d. for the wire cloth. The expenditure under this head amounts to £5 per month for the 30 stamps.

In the place of blankets green baize is used; it costs 3 shillings per yard and has a time of service varying from three to four months. The expenditure per month is equal to £7

for the entire mill. Those which are least worn are always placed in the first row. The washing of the blankets is done by boys, the wages being 7½ shillings per shift. One stout lad will do the work demanded by three batteries, but cannot manage the washing of the blankets belonging to 4 batteries or 20 heads.

The treatment of the ore as carried out at this mill is interesting on account of its simplicity. Before questioning whether it be correct in principle we must examine the ore. This is essentially of the free-milling type and is broken from a large quartz lode traversing schists. The quartz often has a laminated or ribbon structure, which renders it readily broken. Inclusions of country rock are common. Pyrites or other sulphide minerals are present in very small proportion, from about one-half to three-fourths per cent. only. Concentrating tests have shown that the best product will contain only 10 pennyweights of gold, giving a value too low for treatment in this particular locality, and on the small scale required by the necessities of the case. The gold occurs free. Ore containing more than the usual percentage of pyrites is generally below the average grade. The gold is not therefore notably associated with the pyrites. It is usually coarse and often visible. Quartz which in the stopes does not on examination show occasional specks of gold is generally of low tenor. On being crushed the matrix of quartz readily separates from the particles of gold. In the mill it would be expected that the coarsest gold would be found to remain in the mortar box and that that obtained from the first row of blankets would be less fine than that washed from the bottom row. Such is the case; that found in the batteries on cleaning up is very coarse indeed, pieces weighing 5 to 8 pennyweights being occasionally obtained.

The mill is illuminated at night by electricity, and on examining the blanket strakes by the aid of a powerful arc light the yellow particles of gold can be distinctly seen scattered over the green baize. The clean-up indicates the distribution of the gold saving; 230 tons yielded 691 ounces of amalgam. Of these 691 ounces, 270 came from the blanket washings and 421 from the residues in the mortar box. Thus about 61 per cent. remained in the battery. On retorting, 313 ounces

of bullion resulted; and upon melting, this was reduced to 301 oz. 4 dwts., worth £3 19s. 3d per ounce.

The two most striking features of the method of treatment are, first, that no mercury is used in the mortar-box, or indeed, in the mill proper, its use being confined to the after-treatment; and, secondly, that the gold saving is effected by gravity alone. This system is borrowed for the most part from the mills of Clunes, Victoria, and was by them in turn derived from those of Nagyag and Verospotak, in Hungary. It will be allowed that the more simple a mill treatment is, the better, because it is also usually cheaper. Another milling axiom is that the treatment should vary according to the nature of the ore. Here, if the methods employed are elementary, the character of the millstuff is no less strikingly simple. Whether the mill succeeds in the extraction of a proper percentage of the value in the ore is then the question. In this case repeated assays of the tailings from the Phœnix mill prove that excellent work is being done. The composition and character of the ore justify the entire replacement of the ordinary copper plates by blankets, and the successful extraction confirms this.

In milling, as in mining, we are apt to generalize somewhat hastily, and the good work done by his mill has made the manager of the Phœnix, to whom I am indebted for courtesies received, an enthusiastic advocate of blankets and an equally pronounced enemy of amalgamating plates. He communicated to me the following results of an experiment carried out at his mill: Two five-stamp batteries were supplied with 80 tons each of the same kind of ore; No. 1 battery was provided with mercury inside the coffer or mortar box, with copper amalgamating tables outside, with mercury wells, and finally two rows of blankets. No. 2 battery was supplied with no mercury and was supplemented by blankets alone. The results of the test showed that 8 ounces (or 2 pennyweights per ton) more were obtained by No. 2 than by No. 1.

In condemning copper plates the manager equally objects to the use of mercury in the rest of the mill, and would confine its employment to the final collection of the gold in the blanket washings. As a case in point and to confirm the correctness of his ideas, he instanced the Invincible mill, on the

other side of the same range of mountains, where the gold saving was done by the mercury in the battery itself, by wells, by amalgamating tables, and, lastly, by blankets. On ceasing to add mercury to the ore in the mortar box it was found that more gold was saved.

The two instances, at the Phœnix mill and at the Invincible, merit careful examination. Take the second case first. It so happened that I had visited the Invincible mill, though it was then idle. It seems no wonder to me that the addition of mercury to the ore when in the mortar box did not improve the gold saving—that it indeed caused a loss; for the mortar boxes are merely square iron boxes in no way modified to do the particular work required of them. The explanation of the results above quoted is to be found in the fact that the mortars were not designed of a shape adapting them for amalgamation inside, and there was no opportunity given to the amalgam to collect out of reach of the falling stamps, but, on the contrary, the quicksilver added was subjected to a violent agitation which caused it to be floured—that is, broken up into a myriad of small globules. These last are readily borne away by the water, and, escaping with the tailings, also take with them a certain amount of gold with which they may have come in contact.

At the Phœnix mill the experiment quoted is vitiated in a similar way. You cannot make a mortar box a successful amalgamating machine by the mere addition of quicksilver. The batteries of this mill are rectangular in section, with vertical ends and sides, and are in no way adapted for inside amalgamation. To make a fair comparison between the effectiveness of amalgamation as against blanket saving, it is necessary to have the two types of batteries, one roomy and of particular shape, the other narrow and severely rectangular, whose construction has kept in view their suitability to the two modes of milling.

But there is no suggestion intended to be made that blankets could be advantageously replaced at the Phœnix mill by amalgamating plates. Different ores require different modes of treatment. Generalizations are always dangerous. Now, if blankets will arrest your gold, it is obviously not advisable to use an expensive chemical like quicksilver or to

employ an apparatus so troublesome as copper amalgamating plates. Here at the Phœnix the mode of milling is of unusual simplicity, but it is suited to the ore whose gold contents it is intended to extract; and in saying that, one has made the best commendation of any particular system of treatment.

Passing on to another mill, the Premier, at Macetown, is a much smaller plant, but is engaged in the treatment of a somewhat similar ore by slightly modified methods. The mill consists of 10 heads, weighing 750 pounds each. The speed varies from 75 to 80 drops per minute. The height of the drop has a maximum of 9 and a minimum of 6 inches, according to the hardness of the millstuff. The issue or depth of discharge averages 6½ inches, from 6 inches when the dies are new to 7 inches when they become worn down. The depth is regulated by the insertion of a "blind" or blank piece of sheet iron inside the screen frame, which increases the issue at the start when fresh dies have been placed in position. As the dies wear down, a smaller similar piece is inserted and finally the full depth of the screen is utilized. The capacity of the mill is 65 to 70 tons per week of six working days. The grating or screen is of round-punched Russia iron, having 180 holes per square inch. The bullion is .949 fine, and the amalgam yields on retorting 30 to 38 per cent.

The gold saving is done by the mortar box, to which mercury is added, by the copper plates on the tables outside, by wells, and finally by blankets, supplemented by a Berdan pan.

There is no rock-breaker in use; the feeding of the batteries is done by hand. The mortars of the two 5-head batteries are of different patterns. One is more roomy than the other, and therefore discharges the pulp more slowly. Seeing that amalgamation inside the mortar box is desired, the millman is right in preferring the wider coffer, since it gives more shelter to the particles of gold and mercury, and thereby better favors the amalgamation. On examination I found, as was to be expected, that the pulp issuing from the wider mortar was finer than that of the other, though the same kind of screen was used in both.

Contrary to the usual practice the blankets precede the copper plates. On being discharged from the battery, the pulp has a drop of 22 inches before it falls upon the first row

of blankets. This drop serves no purpose except that of spreading the material over the surface of the blanket tables. These last are 12 feet long and 4 feet 3 inches wide, divided into three longitudinal partitions. They slope 1½ inches per foot. The blankets succeed each other in three equal lengths. The first or top row is washed every hour, the second every alternate, and the third every third hour. Then follow the copper-plate amalgamating tables, 9 feet long by 4 feet wide. The total length is subdivided by five wells, one each at the top and bottom, and three others at equal distances between. Of the five, three only are supplied with mercury. They are 3 inches wide and only one-half inch deep.

The residues from the blankets are shoveled from one tub into a second, from which they are fed by a running stream of water into a Berdan pan of 4 feet diameter. Instead of the ordinary ball, a suspended muller, called the "drag," placed at one side of the pan, does the grinding. This modification keeps the grinding and amalgamation separate, thereby preventing unnecessary flouring of the mercury.

A copper plate, 4 feet 8 inches by 2 feet, is placed below the Berdan with the view of arresting any amalgam escaping in the slimes. At the lower end of the plate there is also a mercury well. The Berdan makes one revolution for every three drops of a stamp—that is, 25 revolutions per minute—when the average speed of 75 drops per minute is being maintained.

Of the total amount of amalgam obtained, 60 per cent. is found inside the mortar and 33 per cent. in the blanket washings. The copper tables save the remaining 7 per cent. It was found that by using copper plates below the blankets as against a fourth row of blankets, about 5 per cent. more amalgam was obtained. This last observation is of interest as proving what might otherwise be inferred, namely, that blankets are particularly suited to the saving of coarse gold just as plates are particularly adapted to the arresting of fine gold. The third mill on the list is a comparatively new machine and is of American design. It is to be regretted that the irregular yield of the Nenthorn mines has prevented any reliable tests being made with the view of comparing it with the older plants.

It will be noticed that at none of these mills is there any attempt to concentrate the sulphide minerals. As a rule, the Phœnix being a notable exception, the pyrites of the Otago lodes yield a very good grade of concentrates. There is, however, no chlorination or smelting plant in the province, and any concentrates obtained have to be shipped to Australia for treatment at a cost and delay proportionate to the distance. That fact goes far to explain the neglect of this part of the milling.

Before concluding it will be well to glance briefly once more at the two older mills. Both the Phœnix and Premier lodes carry ore the gold of which is coarse and free. This explains the comparatively crude and very simple method of treatment. Under such favorable conditions blankets are very effectual contrivances for arresting the gold. This system of gold saving is of very early origin. It was used in America before the discovery of gold in California. The mining districts of the Sierra Nevada borrowed it from the miners of Georgia, and they in turn owed it to those of Verospotak and Nagyag, in Hungary. It came back eastward when the discovery of the Gregory diggings started the mining industry of Colorado. It was derived by the millman of Otago, from the mills of Clunes, in Victoria, which, like those of the United States, borrowed it from Europe.

Blankets mark the infancy of milling and belong to the gossan stage of mining. They can only survive those changes in the ore which accompany the increased depth of the mines when that ore remains, as rarely happens, unaccompanied by much pyrites and that pyrites not too closely associated with the gold. It will be noted that the Premier mill uses less water than the Phœnix, due to the fact that the blankets of the latter have a less gradient and a larger surface. At the Premier mercury is added to the ore in the battery, while at the Phœnix this is not done. The latter is probably the more correct practice. The gold is coarse and free, and, other things being equal, when a large percentage can be arrested by the blankets it is probable that the still coarser particles which remain inside the battery would be caught there by reason of their own gravity and without the aid of mercury.

In both mills the final extraction of the gold from the blanket washings is roundabout and clumsy. It should be possible to treat the residues without so much manipulation.

I conclusion, while it may appear that the mills of Otago have but little that can be advantageously imitated by those of Colorado or California, for the sufficient reason that they are adapted to the treatment of an ore of a very simple character, yet the examination of their modes of working can be of value to the American millman in causing him to ponder over the why and wherefore of many parts of his own practice whose advantage he is too ready to accept without previous questioning or consideration.

CHAPTER XIII.

A Review of Australian Practice.

Wet methods of ore reduction still hold the field in the great gold regions of the southern hemisphere. In America it is already otherwise. As the railway octopus slowly spreads out its iron tentacles there is a tendency for the smelter to supplant the mill, for fire reduction processes to replace wet methods of gold extraction. In Australia, however, the smelter as yet rules only over the limited territories of the silver regions. Elsewhere the stamp mill reigns supreme. This condition of the metallurgical practice of the colonies is, of course, in the first place due to the character of the gold ores themselves, for if the treatment appear primitive it is due to the fact that in most of the large producing mining centers the very simple nature of the millstuff has not called for complicated methods, but it is also traceable to the absence in convenient neighborhood to the gold mines of such deposits of copper or lead as would render profitable the smelting of siliceous gold ores. Simple gold-bearing quartz, such as is ordinarily termed "free milling," yields the bulk of the gold production of Australasia.

Victoria, which produces 40 per cent. of the total yield, is as yet mining and milling only the simplest ores. There are, it is true, valuable deposits of refractory material, particularly in the northeastern part of the colony, but at present they make no noteworthy contribution to the general output.

Somewhat similar conditions obtain in New South Wales, where gold was first discovered in Australia, and which now yields 7 per cent. of the total production of Australasia. In the central parts of the colony, in the Lachlan and Bathurst districts, gold is being obtained from millstuff carrying a

notable percentage of pyrites and other sulphides, requiring some grinding process after ordinary plate amalgamation. Around Armidale, in the northeast, the association of anti monial minerals with the gold has often proved a source of annoyance. Notwithstanding these and other exceptional occurrences the yield of New South Wales as a whole can be said to come from comparatively docile ores and by means of simple methods of extraction.

In Queensland, which produces nearly as much gold as Victoria, many metallurgical problems have arisen within recent years. In some cases a successful solution has been reached. At Mt. Morgan, for instance, barrel chlorination has proved triumphant over difficulties which stamp milling was powerless to overcome. At Charters Towers, at the present time the leading gold producing district of Australia, the ore treatment has presented many difficulties. Ordinary stamp milling, followed by a whole paraphernalia of concentrators and pans, holds the field, but its position is being strongly assailed by chlorination. At Ravenswood, a neighboring locality famous for its refractory ores, cyanidation is struggling against many obstacles.

New Zealand, producing nearly 15 per cent. of the Australasian gold output, has a great variety of ores, a fact which would suggest a more marked diversity in the methods of treatment than actually obtains. On the west coast of the south island, at Reefton more especially, the gold comes from quartz ores of comparative simplicity, and the stamp mill does fairly good work. The same may be said of the southern province of Otago, though in the latter region much value has been forever lost by an omission to save the pyrites by concentration, after ordinary battery and plate amalgamation. In the north island, at Hauraki or the Thames, the ores are very complex and the stamp mill is in vain attempting to do satisfactory work under almost hopeless conditions. Wet methods of reduction have survived long after they were fitted to obtain an economic extraction of the values in the ore. In the neighboring districts the cyanide process has been employed with very varying success.

By way of summary it may therefore be said that the millstuff of Australia is for the most part a simple quartz, con-

COMPARATIVE TABLE OF STAMP MILLS.

	Average contents of the ore, pennyweights.	Average milling cost, cents.	Average number of stamps.	Weight of stamps, pounds.	Number of drops per minute.	Height of drop, inches.	Depth of discharge, inches.	Crushing capacity per stamp, tons of 2240 pounds.	Capacity of mill, tons.	Variety of screen.	Number of holes per square inch.	Percentage of concentrates, per cent.	Average gold contents, ounces.	Retort percentage, per cent.	Fineness of bullion, per 1000.	Life of screen, days.	Loss of mercury per ton of ore, pennyweights.	Consumption of water per stamp per minute, gallons.
Clunes, Victoria	9	59	60	890	80	8	4½	2½	150	Perforated copper plate	100	¾	3	40	970	25	⅛	8
Ballarat, "	8½	56	40	950	70	8	3	2	80	Round-punched Russia iron	160	2	2	48	968	12	5	5½
Bendigo, "	9¼	58	40	900	72	9	3½	2¼	90	Same	143	1	2½	50	955	11	7½	6½
Otago, New Zealand	10	70	20	800	77	7½	3½	1½	30	Same and steel cloth	140	*	*	41	930	7	7	4
The Thames, New Zealand	9½	95	30	700	70	8½	2½	1¾	52	Round-punched Russia iron	160	†	†	42	665	6	‡	§
Charters Towers, Queensland	25	300	30	950	74	8	2	2½	75	Perforated charcoal iron	225	‖	‖	35	790	5	¶	¶

*Pyrites not saved as a rule. †Very variable. Saved by blankets and treated in pans. ‡Mercury usually attains a loss of 12 to 20 pennyweights. §Very variable. ‖From 1 per cent. to 70 per cent. From 2 to 20 ounces. ¶Differ widely according to the number of pans and concentrators.

taining from 0.5 to 2 per cent. of pyrites, mixed with a varying proportion of country rock—slate, schist, or sandstone—but that within its wide confines there occur ores in every gradation from the most docile to the most refractory.

The accompanying table will give at a glance the general characteristics of the stamp mills of six of the most representative mining centers. It will serve as a text for the remarks which follow.

The first stamp mill erected in Australasia was that of the Port Phillip & Colonial Gold Mining Company, which commenced work at Clunes in May, 1857. The stamps, 20 in number, had square heads. The process of treatment at the commencement of operations was largely founded upon that of tin dressing as conducted in Cornwall, but the enterprise and good sense of the management was abundantly shown in the succeeding years by the changes made in their methods and by the modification of the treatment to suit the ores of their own mines.

The ore broken from the veins at Clunes is of a very simple kind. It is a white, rather friable, quartz traversed by numerous fractures and cavities in which the gold occurs and from which it is readily detached by the blow of the stamp. Metallic sulphides are present in very small percentage and do not appear to be intimately associated with the gold.

The methods employed in this district are of the simplest kind. Blankets and mercury traps (or wells) do the work usually accomplished by amalgamated copper plates. The concentration of the pyrite is done by Cornish buddles of an improved type. The concentrates are roasted in an ordinary reverberatory and then treated in a Chilian mill, at a total cost of $9 per ton. The work accomplished by the mills has been of the most satisfactory character. The Port Phillip used to extract, as shown by accurate sampling and careful tests, from 85 to 90 per cent. of the value in the ore. There are few milling centers where there is so little room for adverse criticism.

At Bendigo the ore is also a comparatively simple quartz, but it is harder than that mined at Clunes, and it contains an increased percentage of pyrites and other sulphides. The finer crushing which the ore requires indicates these condi-

tions. The character of a millstuff is, however, also determined by the amount and kind of country rock mixed up in it. The Clunes ore is fairly clean quartz, while that of Bendigo carries a large proportion of included sandstone and slate. Too much of the latter makes slimes and is inimical to successful amalgamation.

The milling practice of Bendigo is likewise simple. Ordinary plate amalgamation is followed by a short length of blanket strakes succeeded by concentrators. The latter are percussion tables of an imperfect type. The concentrates thus obtained go to the "pyrites works" where they are roasted and then either treated by grinding in arrastras or by chlorination. The Plattner or vat method has given place to that form of the barrel process which bears the names of Newberry and Vautin. Ordinary reverberatory and mechanical (both revolving cylinders and vertical shaft furnaces) roasters can be seen working side by side. The rate for treatment is £3, or $15 per load. A "load" of Bendigo pyrites weighs, on an average, 30 hundredweights.

At the neighboring district of Ballarat much the same conditions prevail. The ores contain an increased amount of sulphides, due to the presence of a little more galena and blende, but in spite of this the percentage remains very small when compared to that of other mining centers in Australia and America.

The stamp mills are very similar in arrangement to those at Bendigo. The blanket washings are usually treated in Berdans. Percussion tables, which are not self-discharging, are in general use for collecting the pyrites. Frue vanners have been very successfully used at the North Cornish Company's mill, at Daylesford. The concentrates go to chlorination works, using the barrel process.

The three leading milling centers of Victoria, which have just been passed in review, have many features in common, but Clunes is the only one which can show a mill at all completely equipped. There are no rock-breakers and no automatic ore-feeders in use either in the Bendigo or the Ballarat districts, though at Clunes they were introduced as early as 1865. The absence of these very necessary parts of a com-

plete stamp mill is an evidence of an obstinate disregard of modern progress in milling methods which is as regrettable as it is inexplicable.

In New Zealand, Otago, and the Thames, one in the south and the other in the north island, are in strong contrast. The southern province uses methods which originated largely from the experience obtained at Clunes. Gold saving by blankets can be seen contrasted with the more modern plate amalgamation. The ore carries a noteworthy percentage of pyrites, which in many instances is known to lock up value. The not infrequent absence of any attempt at concentration is therefore very noticeable. It is, however, largely explained by the fact that there are no works in the island which treat concentrates, and as a consequence they have to be sent to Australia at a cost in shipping charges, etc., which is almost prohibitory.

Going to the north island we find the *reductio ad absurdum* of stamp milling in the treatment of the complex gold and silver ores of the Thames district. Here the millstuff carries free gold, native silver, native arsenic, sulphides of silver and of antimony, arsenical pyrite, galena, blende, tellurides of gold and silver, and other minerals in great complexity and variety. This material is subjected to stamp milling, followed by blankets whose washings are treated by grinding and amalgamation in pans. The result of this process is that barely 50 per cent. of the values are saved, and the subsequent treatment of the tailings is almost as remunerative as that of the ore itself. This is an instance of the blind disregard of the first axiom of all successful milling, namely, to adapt the process to the ore.

The north island of New Zealand contains many very valuable depositories of the precious metals, but they are too often found locked up in refractory matrices. At Kuaotunu, Karangahake, Te Aroha, Waihi, Waiorongomai, Puhi-puhi, Kapanga, and other localities with picturesque native (Moari) names, there are ore deposits which have as yet baffled the best metallurgical ingenuity. In this mining region, as has been the case elsewhere the wide world over, large and costly plants have been erected before those in charge had proper assurance of the capability of the mine to supply the ore required by the mill, or of the capability of the mill to satis-

factorily treat the ore. The handsome concentrating and leaching (cyanide) plant of the Sylvia Company, on Tararu Creek, is an instance of the former; and what little now remains of the extensive concentrating and smelting plant of the Te Aroha Gold and Silver Company at Waiorongomai is an example of the latter.

The cyanide process has been struggling here for many years. It was first introduced at the Crown mine, Karangahake, and battled in vain against incompetence and ill-luck. At the present time it is being used with varying success at several milling establishments in this region, but in addition to the ordinary difficulties common to new leaching processes it has to bear the incubus of an extortionate royalty.

Queensland is a great field for the metallurgist. At Gimpie, Charters Towers, Croydon, and elsewhere, the stamp mill extracts the bulk of the gold, but at Ravenswood and Mount Morgan it has already given place to other methods. If the Mount Morgan mine had not contained an ore deposit of extraordinary richness the failure of the stamp mill might have proved its death blow. The gold, though free and enclosed in a simple quartzose gangue, was what is often termed "rusty." Analyses showed that though of unusual fineness, from 997 to 998 per thousand, it was coated with hydrated oxide of iron. A rough calcination, followed by barrel chlorination, formed a method of treatment which proved entirely successful. The works erected have a capacity of 1,700 tons per week.

Of the northern gold fields Charters Towers is now easily first. It is one of the most successful, as regards proportion of expenditure to returns, of modern mining districts. The ore is of high grade. The mine which headed the list for 1892 (The Victory) produced 37,752 ounces of gold from 8,775 tons, paying £97,500 in dividends.

The ores of Charters Towers are heavy with sulphides and are badly adapted to reduction by the stamp mill. However, here, as in Gilpin County, Colorado, such modifications of the ordinary methods have been made as to give much better results than at a first glance would be thought possible. The millstuff contains on an average about 5 per cent. of sulphides,

but this often increases to 20, 30, and occasionally even to 60 or 70 per cent. The stamp batteries are amalgamating as well as crushing machines. A certain proportion, averaging from one-third to one-half of the total gold extracted, is yielded by amalgamation inside the mortars. The pulp runs off the outside amalgamating tables into circular concentrating machines, the pyritic material being afterward subjected to grinding and amalgamation in pans. The concentration is not carried very far, viz, up to 60 or 70 per cent. of sulphides. Of pans there seems to be no end. At the Excelsior mill, for instance, I counted 50 stamps, followed by 10 Brown & Stansfield concentrators, succeeded by 16 Blake & Wheeler pans and 49 Berdans.

The treatment is expensive and only partially successful, for at the close of the milling operations not more than about two-thirds of the value in the ore has been extracted. That grinding and amalgamation are inefficient in extracting the gold of the concentrates is proved by the fact that the chlorination works sometimes buy the pan tailings.

There are several chlorination plants in the district. The vat process is employed. Roasting costs $8 and chlorination $4 per ton. The grinding of the concentrates in pans can be shown even at the present time to be less advantageous than chlorination.

Notwithstanding the high price of chemicals and fuel, chlorination is destined to grow in favor, especially when more care is given to the concentration. At the Burdekin mill 24 Frue vanners are at work, and by their use much cleaner concentrates are obtained than from the other concentrators employed in the district. The time is shortly coming when amalgamation methods will, at Charters Towers, be put aside and direct concentration followed by chlorination succeed the existing milling practice.

Thus we find, as the result of a brief survey of the milling methods of the colonies, that the gold fields of the southern hemisphere, like those of our own side of the world, are the scene of trial of many new amalgamating machines and the battlefield of a multitude of new processes. The clumsy old stamp mill and simple amalgamation treatment still hold

their own wherever gold ores are not of a complex character. The colonial may do well to take to heart the fact that no stamp mill perfect in every respect has as yet been built anywhere, and that in his own case there is room for improvement, particularly in that arrangement of a mill which promotes automatic handling of the ore, which should make him regretful of the past and hopeful of the future.

CHAPTER XIV.

THE WEAR AND TEAR OF A MILL.

To illustrate the functions of the parts of a stamp mill we may employ the familiar analogy of the hammer and anvil. The stamp, viewed as a whole, is the hammer whose impact crushes the ore, and similarly the bottom of the mortar box may be considered the anvil upon which that crushing is performed. The work is, however, more particularly done by and upon certain small portions of the mechanism, such as the shoes and dies, which are therefore made so as to be replaceable when they break or become worn out.

In modern milling practice the shoes and dies are made of a variety of kinds of iron, but it was not always so. In the valleys of the hills of Transylvania (Hungary) there can still be seen wooden stamps shod with agate falling upon a stone pavement lining a wooden mortar box. In the United States and Australia it will be found that the material of which the shoes and dies are made varies from chrome steel to wrought iron, and that the use of this or that variety of metal is a question to be decided quite as much by the distance from the foundry as by the initial cost or the excellence of the material.

The shoes and dies form those parts of the mill which finally subjugate the hardness of the ore preparatory to delivering it to the agents of amalgamation; it is on them, therefore, that the brunt of wear and tear necessarily falls, and, other things being equal, the hardest ore will cause the greatest abrasion of iron. But these "other things" are not always equal, and we therefore find that a very wide variation is effected by certain conditions, among which may be mentioned the state of division in which the ore is delivered (large or small, even

or uneven), the height that the stamp drops, the depth of the discharge or issue, the regularity of the feeding, and the shape of the mortar box itself.

For the purpose of our inquiry into the variations in the wear of the shoes and dies, it will be found convenient to express the excellence of their service by the number of tons of ore crushed from the moment when they are first placed in position to that time when they are discarded as being worn out and unserviceable. The difference in weight between the new shoes and dies and their worn-out remnants represents the amount of metal consumed in the mechanical reduction of a certain number of tons of ore. If the remnants can be sold (as scrap) to a neighboring foundry the return so obtained will help, to a small extent, to diminish the initial cost. Figures will, however, be most expressive. In the accompanying comparative table there are given the results of the use of different kinds of shoes and dies in various districts and under varying conditions. The figures were obtained by the writer during the past four years and represent the practice of eight mining centers, four in the United States and four in Australasia; they give the work done and the expense incurred at certain periods and under certain conditions, which, owing to alterations in the construction of the mills and the diminution of freights, are ever shifting.

A glance at this tabulated statement will indicate the wide difference between the results obtained at the different mills. It will be our business to inquire into the reason of these great variations, and to endeavor to determine whether they are warranted by the diverse conditions which obtain in milling centers so wide apart.

The wear of the shoe varies from 3.6 ounces to 21.3 ounces of metal per ton of ore crushed, while that of the die has a minimum of 3 ounces and a maximum of 7.9 ounces. In the matter of expense the least cost of the shoe is at the rate of 2.02 cents and the greatest 7.64 cents per ton of ore, the minimum cost of the die is at the rate of 0.71 cent and the maximum 5.5 cents, while the combined cost under this head varies from 4.06 cents to 13.14 cents for every ton of ore crushed.

Brief reference to each milling center quoted will be of

service in explaining some of these differences. In Gilpin County, the oldest established mining center of the State of Colorado, we find that cast iron is the metal employed. Chrome steel shoes and dies, manufactured at Brooklyn, N. Y., have been tried, but the millmen of Black Hawk prefer the product of the local foundries. It is mainly a question of economy. Though the steel wears in the ratio of only 9.3 ounces per ton of ore as compared to 15.7 ounces of cast iron, yet the former costs twice as much as the latter, and therefore the resulting expense is in the proportion of 7.15 cents to 5.95 cents. Here, as is usually the case, the scrap iron is salable at 1 cent per pound, while the steel remnants are worthless. In the actual working of the mill it has been found that cast iron wears more evenly than steel, the latter tending to develop an irregular surface; this (called "cupping" by the millmen) diminishes the crushing surface and increases the vibration of the mechanism of the stamps.

The wear in this district is excessive, though the ore is of less than ordinary hardness. This is due in part to the extremely long drop prevailing in the mills, namely, from 16 to 20 inches, but it is also caused by the absence of rock-breakers and automatic feeders.

At Grass Valley, in Nevada County, Cal., the ore is extremely hard. It is composed of white quartz and a varying but very large proportion of the syenitic country rock. The metal of the shoes is chrome steel, which comes from New York, while the dies are cast at the local foundry and contain a fifth part of steel, being the remnants of worn-out shoes. It has been found, at the North Star mill, that the use of cast-iron dies with steel shoes materially adds to the life of the shoes, and is much better than the use of the same metal in both shoes and dies. At the Empire mill both cast iron and steel dies are in use. There does not appear to be any marked difference in their manner of wear, and the steel does not exhibit "cupping." The seeming contradictory feature of this experience, as against that of Gilpin County, Col., is to be explained by the fact that the more rapid drop of the California mill, accompanied as it is by a turn of the stamp, tends to equalize the wear and to maintain an even surface better than the very slow drop of the Colorado mill.

At the Idaho mill chrome steel from Brooklyn has been found to give much longer service than steel shoes and dies manufactured in California. When the chrome steel and cast-iron dies do not show much difference in the cost per ton of ore crushed, it is found that the millmen prefer the former because, though more costly, they last longer and therefore require less frequent replacement.

At Angels Camp, in Calaveras County, Cal., the conditions are very favorable to a minimum wear. At the time of my last visit the height of drop was 5 to 6 inches and the stamps dropped 95 times per minute. Since then the principal plant, the Utica mill, has been enlarged and the methods of milling slightly modified. The Stickles mill has also come under the Utica management. The ore of this district is particularly soft; the quartz occurs in small seams forming very wide lodes, in which there is more slate than quartz. The millstuff is readily crushed by the stamps. Experience has taught the local millmen that steel shoes and cast-iron dies give better results than shoes and dies of similar metal. The difference between the wear of steel on cast iron, and of cast iron upon cast iron, is found to be very small, while the cost per ton varies by a fraction of a cent only.

At Mammoth, in Pinal County, Ariz., the conditions are very different from those with which we have had to deal in any of the three milling centers previously noted. The nearest railway is 52 miles distant, and there is no foundry able to provide cheap castings. Chrome steel shoes and dies are preferred because the freight on cast iron is so high (from Denver, 2½ cents per pound) that the extra length of service of the steel more than compensates for the increased first cost. Steel costs 11 cents per pound, delivered, as against about 7 cents for cast iron. Here there is no doubt as to the fact that the greater length of service of chrome steel much more than compensates for its slightly higher cost.

The ore of this district is not very hard and the wear must be considered excessive. It is due to some extent to the absence of sizing-bars (grizzlies) in the mill and the consequent unevenness of the material delivered to the stamps, and it is also in part caused by the small but varying depth of discharge which has a minimum of 1½ and a maximum of 6 inches.

WEAR OF SHOES AND DIES IN STAMP MILLS.

	Name of district.		Metal.	Weight. New, pounds.	Weight. Worn out, pounds.	Ore crushed during time of service, tons.	Metal worn per ton of ore crushed, ounces.	Cost of the metal per pound, cents.	Value of the scrap, cents.	Cost per ton of ore crushed, cents.	Total cost per ton of ore crushed, cents.	Remarks.
United States.	Gilpin County, Col.	Shoes,	Cast iron . . .	83	27	80	11.2	4	1	3.82	5.95	No rock-breaker; no automatic feeders; ore moderately soft; long drop; wear of the dies is very variable.
		Dies,	Same	48	26	78	4.5	4	1	2.13		
		Shoes,	Chrome Steel .	111	31	202	6.3	8	. .	4.39	7.15	
		Dies,	Same	55	25	159	3.0	8	. .	2.76		
	Grass Valley, Cal.	Shoes,	Chrome Steel .	152	48	251	6.6	9	1½	5.17	9.43	Rock-breakers and feeders; ore very hard; dies contain ½ steel scrap.
		Dies,	Cast iron . . .	93	45	96½	7.9	4½	1½	4.26		
	Angels Camp, Cal.	Shoes,	Chrome Steel .	175	40	585	3.6	9	. .	2.70	4.06	Rock-breakers and feeders; ore soft; short drop.
		Dies,	Cast iron . . .	95	35	275	3.5	4½	1½	1.36		
	Mammoth, Ariz.	Shoes,	Chrome Steel .	132	40	190	7.7	11	. .	7.64	13.14	Ore medium; rock-breakers and feeders; no grizzlies.
		Dies,	Same	120	37	240	5.6	11	. .	5.50		
Australasia.	Bendigo, Victoria	Shoes,	Cast iron . . .	180	38	115	19.7	2½	¾	3.66	4.37	No rock-breakers and no feeders; ore variable but medium hardness.
		Dies,	Wrought iron,	98	26	335	3.4	2½	⅛	.71		
	Clunes, Victoria	Shoes,	Cast iron . . .	196	56	105	21.3	2¾	¾	4.67	5.55	No rock-breakers; feeders used; ore almost entirely quartzose.
		Dies,	Wrought iron,	138	30	420	4.1	2¾	⅛	.88		
	Harrietville, Victoria . . .	Shoes,	Fagot iron . .	172	38	185	11.5	3½	. .	3.25	4.72	No rock-breakers; feeders used; dies wear very irregularly.
		Dies,	Same	84	37	200	3.7	3½	. .	1.47		
	The Thames, New Zealand,	Shoes,	Cast iron . . .	170	51	135½	14.1	3	1	3.40	5.65	No rock-breakers or feeders; ore of very variable hardness.
		Dies,	Same	108	42	141	7.5	3	1	2.25		

An Arizona Stamp Mill.

Going to the southern hemisphere, we find the wear and tear of shoes and dies is very much in excess of that to be noted in the United States. At Bendigo both shoes and dies are furnished by the local foundries. The former are invariably made of cast iron and the latter of wrought iron. The local prices are £12 per ton for both "hard" metal shoes and "soft" metal dies. Old cast iron brings £4 per ton and wrought iron scrap £1½ per ton. Steel, when imported from England, costs £30 per ton, and while it has been found to give much longer service than the local castings, its high price renders its use prohibitive. The shoes generally weigh from 180 to 195 pounds and are usually 9 inches high by 9½ to 10 inches in diameter. When worn out they weigh from 35 to 42 pounds. They give very poor service, 16 to 25 ounces of iron being worn away for every ton of ore crushed. Neither do they wear down evenly, but exhibit an irregular surface which much impairs their usefulness. The dies weigh from 80 to 110 pounds, their depth varies from 3½ to 4½ inches. When worn out they weigh from 20 to 30 pounds. They give excellent service, wearing slowly and evenly. The loss of iron per ton of ore crushed varies from 3½ to 13½ ounces.

Notwithstanding the excessive wear of the shoes, yet by reason of the excellent service given by the dies and because of the low first cost of the metal of both shoes and dies, the total cost is only about 4½ cents per ton of ore, a figure which compares well with the same item of expense at the American mills.

At the Thames district, in New Zealand, the excessive wear of the shoes is again marked and is again due to the absence of rock-breakers and automatic ore-feeders, causing the delivering of irregularly broken millstuff at a variable rate dependent upon the caprice of a combination of boy, shovel, and sledge hammer.

Both shoes and dies are made of cast iron obtained at a local foundry. They differ in that the former is, and the latter is not, chilled. The price is £13 per ton. Old scrap is taken at £5 per ton.

The shoes weigh from 168 to 215 pounds and vary in depth from 9 to 10 inches. When worn out they weigh from 30 to 50 pounds. The wear is equivalent to from 6 to 16 ounces of

iron per ton of ore crushed, the minimum rate being only obtained with soft surface ores.

The dies when new weigh from 80 to 116 pounds; they are usually octagonal and they have a thickness varying from 3½ to 5 inches. When worn out they weigh from 35 to 45 pounds. The wear varies from 5½ to 8½ ounces per ton of ore crushed.

The service given by both shoe and die is poor, and is largely due to the very bad, irregular feeding which is common to the mills of the district. The very variable hardness of the ore and the little care taken to maintain a constant depth of discharge are also factors in the production of this excessive waste of metal.

At Clunes, as at Bendigo, cast iron is worked against wrought iron. The shoes weigh 192 to 198 pounds when new, and 45 to 60 pounds when worn out. They do not wear so evenly nor last so long as the dies, which weigh 130 to 140 pounds when new, and from 25 to 35 pounds when discarded.

The ore treated at the mills of this district is very nearly clean quartz, and though it is readily broken, its ultimate pulverization produces a heavy wear and tear. The South Clunes United mill has, unlike the other two principal plants (now idle), no rock-breaker, and therefore the wear of the shoe is very excessive. The low cost of the castings, however, makes the final cost far from high, since it amounts to only 5½ cents per ton of ore treated.

At Harrietville, also in the colony of Victoria, the shoes and dies are made of the same material, viz, fagoted white iron. It is obtained from a Melbourne foundry. The cost is £16 per ton. The castings are unsalable at Harrietville.

The shoes are 9 inches high by 9½ inches in diameter; they weigh, when new, 172 pounds, and when worn out, 38 pounds. They give good service and retain a fairly even surface.

The dies are octagonal and 4 inches deep. They weigh 84 pounds when new, and 37 pounds when discarded. Their time of service is less uniform than that of the shoes, and they do not retain so even a surface. The metal of which they are made should be, but is not, more tough than that of the shoes. The total cost per ton of ore amounts to 4¾ cents.

We have now passed in review the eight districts whose figures are given in the comparative table. Can anything be

learned from the comparison or are we to decide that the results are too contradictory to warrant any generalizations? We shall, I believe, find that there is more harmony in the evidence of these figures than would at first sight appear.

Take, for instance, the fact, which is readily apparent, that the wear of the dies does not vary in an equal degree with that of the shoes. The minimum to the maximum is in the former as 1 to 2.6, but in the latter it is as 1 to 5.9. The explanation is to be sought for by referring to the analogy of the hammer and anvil. The die, which is the anvil, is protected by the ore which lies upon it, and the brunt of hard work falls upon the shoe, which is unprotected.

The ore upon the die is a cushion, and the more constant the thickness of that cushion the less the wear of the die. Here is where bad feeding does its evil work. The regular supply of ore particles of even dimensions is never obtained by the use of the sledge hammer and shovel; the absence of sizing-bars (grizzlies) and of automatic feeders is a potent cause in diminishing the time of service of the dies. In this connection it may be pointed out that the depth of discharge—the distance from the bottom of the screen to the top of the die—is a factor whose importance is universally underestimated in stamp milling. In many mills, particularly in Australia, it will vary in the ratio of 1 to 2, or even 1 to 3½; such variation must necessarily assist in impairing the regular working of the mill and cause a heavy waste of iron, because under such changing conditions it is doubly difficult to regulate the thickness of the ore upon the die.

Experienced millmen always maintain that the use of a rock-breaker diminishes the wear of the shoes and dies. Is this confirmed by the tabulated figures? If you examine the results obtained under varying conditions, you will find that every milling center which does not use the rock-breaker, preferring the simple barbarity of sledge-hammer treatment, has an excessive wear, which is most noteworthy in respect to the shoe. The effect upon the die is not marked, because, as explained above, the cushion of ore upon it serves as a protection, equalizing the wear and tear.

It will be noticed that the mills of Gilpin County, the Thames, Bendigo, Clunes, and Harrietville, though working

under a variety of conditions and crushing ore of very different hardness, have each of them a wear of iron exceeding 10 ounces per ton of ore crushed, while the rock-breaker districts,—Grass Valley, Angels Camp, and Mammoth,—also working with ores which have a very different character, from very soft to extremely hard, show none of them a loss of iron exceeding 7½ ounces per ton of ore. In the cases of Grass Valley and Bendigo, the contrast is very marked, since while the millstuff of the California district is extremely hard, yet the liberal use of rock-breakers renders the wear only one-third that of the Australian center.

These results are in accord with common everyday experience. It is the hammer that must suffer the brunt of the unnecessary wear entailed by the attempt to crush particles of stone of unequal size. One moment the stamp falls upon particles of ore fine as dust, but the next it is dancing upon a large stone which it does not break at the first blow, doing useless work and having its iron unnecessarily abraded and chipped.

The low price of castings in the milling centers of the antipodes accentuates the high prices which still obtain in the mining camps of the United States. These high prices seriously handicap the economic success of mining and milling in the Great West; they are in many instances out of date and out of keeping with the diminution in freights and the cheapening, all over the world, of everyday commodities.

The great diversity of metal used in the shoes and dies of the various mills is due to a rule-of-thumb policy. The analogy of the hammer and anvil shows that the metal of the anvil should be, and is, softer and tougher than that of the hammer. It should be so in the case of the shoe and die. The best results are to be obtained not so much by the employment of the hardest material, as by having the die made of metal more tough,* less brittle, than that of the shoe. Thus steel and cast iron, chilled and unchilled iron, cast and wrought iron, are combinations which generally give good service. The excellent work done by wrought-iron dies at Clunes and Bendigo should teach a lesson to those who are

*The use of chrome steel shoes with manganese steel dies is to be highly commended.

seeking to obtain a metal of excessive hardness for the manufacture of dies.

In summing up we find, as common sense and ordinary experience would suggest, that in the matter of the shoes it is the use or otherwise of the rock-breaker (with grizzly and self-feeder) which will most affect their wear, and in respect to the die the desideratum is a metal which shall be less hard and more tough than that of the shoe which falls upon it.

CHAPTER XV.

The Flouring of Mercury.

Millmen rarely have a clear idea of the reasons which cause the mercury used in a stamp mill to refuse to amalgamate with the gold particles and to be carried away in the tailings. "Sickening" and "flouring" are the terms used, but with a confusing carelessness. Thus a recent writer speaks of the loss of mercury in a certain mill as being "greatly increased by bunches of ore carrying oxide of manganese, which causes the mercury to 'flour.'"

Although the causes which produce what is known as "floured" mercury may not be accurately or completely known, I nevertheless feel that the writer, in the instance above quoted, like others in other cases which have come under my notice, has misconceived the meaning of the term which he uses. In the same way the reactions which produce the "sickening" of mercury are but rarely, and then only vaguely, understood.

The subdivision of mercury into minute globules is "flouring." The term has, of course, been chosen because the subdivision referred to is carried so far as to cause the mercury to resemble a whitish-gray powder. When mercury is subdivided the globules are very apt to become coated with a film of any foreign substance which may be present, the effect of which is to prevent them from coalescing or reuniting. Thus, therefore, "sickening" follows "flouring" and renders the latter condition permanent by the preventing of the reunion of the subdivided particles of mercury. "Flouring" by itself is not necessarily injurious, but rather favorable to amalgamation, if only the minute globules of mercury alloy themselves with the gold in the ore before they become coated

with foreign matter, such as will hinder amalgamation and at the same time render them readily transported by the water running over the plates.

"Flouring" always occurs in a stamp mill to a varying extent; it is due to the violent agitation of the pulp, which takes place under the stamps, and to the cutting of the mercury (fed into the battery) by sharp grains of ore. The "sickening" which may then ensue, and generally does, more or less, is due to causes either mechanical or chemical, or both.

Thus, for instance, the globules of mercury may become coated with grease from lubricants used in the mine or mill; they may become covered with a film of some unctuous mineral, such as talcose clay. Grease dropping from the guides often does mischief. To prevent it as much as possible I would recommend the use of a mixture of one quart of plumbago in one gallon of molasses. Similarly, the varnish on the surface of new screens is injurious. It is well, therefore, before putting them in position, to soak them in a hot solution of concentrated lye. Where, on the other hand, the ore itself carries an excess of clay, the best thing to do is to mix some granular millstuff with the ore fed into the battery. In some mining districts the gold-bearing quartz occurs in veins traversing alternations of slate or schist with sandstone or some other granular rock. In such cases it only necessitates a little care in feeding the mill with a judicious mixture of the granular and the softer, more clayey, material.

The use of hot water in the stamp mill, to prevent freezing in a cold climate, or to aid amalgamation in a warm region, often leads to the employment of condenser water. This is a serious mistake, because such water usually carries the millman's worst enemy—grease of some kind. I remember well visiting a mill at Ballarat and being surprised to see steam escaping (it was summer time) from the water running over the plates. The millman told me he was using condenser water, and when I suggested that it was a dangerous aid to amalgamation he demurred. A few days previous I had examined the launder conveying the condenser water at a neighboring mill, and had found the sides and bottom covered with a slimy ooze which could not but be deadly to the

efficiency of mercury in a mill. I asked him what amount of mercury the mill consumed, expecting to be able to show him triumphantly that he was incurring an excessive loss of that volatile metal. But, to my discomfiture, I found that the consumption per ton of ore crushed was slightly less than at his neighbor's plant where condenser water was not used. Somebody evidently was mistaken. On further skirmishing about the mill I found that it was the practice of the foreman to add 5 pounds of quicklime to each battery of 5 stamps every 24 hours. Although intended primarily to neutralize any excessive acidity in the battery water, the lime, as an alkali, was also a solvent* for the grease present in the condenser water and was serving as an effective antidote.

Many of the patent amalgamating machines daily invented have as their underlying principle the idea that the more you bring the gold into frequent contact with the mercury, the more complete the amalgamation will be. The inventor usually sets out to obtain such frequency of contact by compelling the ore to pass through a bath of mercury, or else he turns the mercury into a spray, or mixes the ore and the mercury violently together, or has some other scheme of which the essential feature is that the mercury is cut up and subdivided into particles of more or less minuteness. Such ideas would be well enough were it not for the fact that it is much easier to cause mercury to subdivide than to recoalesce, since of the large amount of foreign substances present in a pulverized form there are always some which at once proceed to coat the globules of mercury, preventing their reunion and rendering them easy of transport by water. A simple instance can be cited in the case of the amalgamating barrels used in many mills for the treatment of blanketings, pan tailings, skimmings, etc. It is usual to add pieces of iron, such as old bolts, fragments of shoes and dies, etc., in order to promote a grinding action. Very often the speed of the barrel is too rapid or the quantity of scrap iron is too great, and if you take a pan and wash a few handfuls of the waste ejected from the barrel you will find a large amount of floured mercury.

*Through saponification.

"Sickening," again, may be due to chemical causes, the mercury probably becoming in some instances covered with an oxide or even a sulphide of itself. In the case quoted at the beginning of this chapter the cause may have been partly chemical, the oxide of manganese giving up some of its oxygen to the mercury, or partly mechanical, if the oxide of manganese was in its common pulverulent condition such as would render it easy to coat the globules of mercury.

Cyanide of potassium, sodium amalgam, and other reducing agents, induce a reunion of the particles of mercury probably because of the vigorous action of hydrogen in a nascent state liberated while in contact with the mercury. An electric current similarly helps to counteract sickening. Again, I might quote the use of plates made of Muntz metal (such as are commonly employed in certain parts of New Zealand), which, being an imperfect alloy of copper and zinc, sets up a feeble local galvanic action, electrolizing the water, liberating the hydrogen, which in turn reduces any oxides which may be coating the quicksilver.

Thus, therefore, I would define "flouring" as the minute subdivision of mercury by mechanical causes, and "sickening" as the rendering of such a condition permanent by the intervention of a coating of some foreign substance, effectually preventing the coalescence or reunion of the globules previously formed.

CHAPTER XVI.

COMPARISONS.

The material of this chapter has already appeared in Vol. IV of *The Mineral Industry*,* and as it summarizes the information given in the preceding pages of this book, it is now, by the kind permission of the publishers, reproduced.

In the accompanying tabulated statement an endeavor has been made to exhibit the distinctive features of the milling practice of representative districts in several countries. It is very difficult to arrive at "average" figures, and it is not always easy to determine which mills are typical and which are abnormal in their methods. Nevertheless it is hoped that the data given, which are founded on a personal knowledge of each locality, will serve as a trustworthy basis of comparison.

District.	Labor.	Shoes and dies.	Water.	Fuel.	Supplies, etc.	Total.
Black Hills. . . .	15	2	20	19	14	70
Gilpin	42	5½	. . . . . .	10	17½	75
Grass Valley . .	32	9	31	. . . . . .	8	80
Amador	20	4½	17	. . . . . .	4½	46

Even the well informed will be surprised at the costs of treatment given in the second column of the table. That the large establishments of the Homestake Company (in South Dakota) should not be able to work with any considerable diminution of the expense incurred by the smaller and much less completely equipped plants of Black Hawk (in Colorado), in spite of a rapidity of crushing four times as great, is a fact demanding an explanation. That the mills of Grass Valley (in California), which are the model plants of this country, should treat their ores at a cost greater than either of the above-quoted regions seems also odd.

* Published annually by the Scientific Publishing Company of New York.

An analysis of the costs of milling in the four representative American districts will indicate the causes underlying these anomalous results. These figure are per ton of ore and are given in cents.

The item of labor is dependent upon the rate of crushing and the automatism of the mill. In the latter regard the Gilpin County district is the only one exhibiting defects, for the mills of the other three are uniformly provided with rock-breakers, self-feeders, and other appliances inseparable from an economic handling of the ore. And although an inadequate equipment of labor-saving machinery still remains a characteristic of the old plants at Black Hawk (in Gilpin), it is well to add that the new mills erected in other parts of Colorado during recent years have been quite up-to-date in this respect. This is not true of the Australian colonies, however, for there even new mills have been designed on obsolete lines, and a plant recently built at Bendigo perpetuates the ancient barbarism of breaking and feeding the ore with hammer and shovel.

The labor cost in the Black Hills is less than it is in California, notwithstanding a higher rate of wages,* because the crushing capacity of the batteries is nearly double. This is largely due to the employment of a mortar of a most excellent design, promoting amalgamation while hastening pulverization. The labor cost at Grass Valley is higher than that of its neighbor, Amador, because the crushing rate is in the proportion of 2 to 3, itself a consequence of a decidedly harder ore. The maximum cost which distinguishes Gilpin is traceable to a low rate of crushing accompanying the absence of labor-saving devices.

The cost in shoes and dies exhibits a very striking variation because the price of the iron or steel used is dependent upon purely local conditions, such as the distance from the foundry. The wear, as measured in ounces of metal consumed per ton of ore crushed, is as follows: Black Hills, 13; Gilpin, 14½; Grass Valley, 16; Amador, 15. The Homestake Company makes its own dies and buys the shoes in large lots, hence the cost is relatively small. The Grass Valley mills use steel for

* Ordinary laborers get $3 per shift. In Colorado and California the rate is $2.50 The skilled workmen are paid proportionately.

VARIATIONS IN STAMP MILLS FOR THE TREATMENT OF GOLD ORES.

Name of district	Yield of ore, dwts.	Cost of milling, cents.	Stamps in mill.	Weight of stamps, lbs.	Drops per minute.	Height of drop, in.	Depth of discharge, in.	Crushing capacity, tons	Description of screen in use.
UNITED STATES:	(a)	(b)			(c)		(d)	(e)	(f)
The Black Hills, S. D.	4½	70	160	850	85	9½	10	4.0	No. 8 (35 mesh) diagonal slot Russia iron.
Gilpin County, Col.	6-8	75	75	550	30	17	14	1.0	No. 1½ (50 mesh) burr slot planished iron.
Grass Valley, Cal.	5-7	81	40	850	85	7	4	1.6	No. 0 (40 mesh) perforated tin plate.
Amador County, Cal.	3½-5	45	40	750	95	6½	7	2.4	No. 7 (30 mesh) angle slot Russia iron.
AUSTRALIA:									
Bendigo, Victoria	9-9½	58	40	900	72	9	3½	2.3	Round-punched Russia iron, 148 holes per sq. in. (30 mesh).
Ballarat, Victoria	8½-9	56	60	1000	73	8¼	2	2.4	Round-punched Russia iron, 120 to 200 holes per sq. in. (20 to 40 mesh).
Clunes, Victoria	7-9	59	60	890	80	8	4½	2.8	Perforated copper plate, 81 to 100 holes per sq. in. (30 mesh).
Charters Towers, Queensland	25	300	30	950	74	8	2	2.6	Perforated charcoal iron, 225 holes per sq. in. (50 mesh).
NEW ZEALAND:									
Otago, South Island	10-12	70	20	800	77	7½	3½	1.5	Round-punched Russia iron, 148 holes per sq. in. (30 mesh).
The Thames, North Island	7-9½	95	30	675	68	8	2	1.6	Round-punched Russia iron, 160 to 180 holes per sq. in. (35 mesh).

(*a*) The figures in this column indicate the yield per ton of the ore treated. A pennyweight is approximately equal to one dollar or four shillings. The figures are those of representative mining companies, and do not apply to either unusual bonanzas or unprofitable mines.

(*b*) These costs are obtained from representative establishments and for periods of one year or more.

(*c*) The slowest drop is 26 per minute and the quickest 110.

(*d*) This gives the average issue between the time of placing new dies and the time when they become worn down so as to require replacement by a fresh set.

(*e*) Short tons of 2000 pounds.

(*f*) Different mills at different times use a great variety of screens. The prevalent type is given in this column. The mesh, in parentheses, gives a basis for an approximate comparison of the relative fineness.

their shoes and local castings for their dies. The price of the former is high, since they come across the continent—from Brooklyn. Furthermore, the ore crushed in this district is very hard. The Amador mills use shoes and dies made at Sutter Creek, in the same county, and sell back the remnants. The Gilpin County plants are provided with local castings and also resell the scrap. The greater softness of the ore of this region is offset by the high drop which is conducive to excessive wear.

The cost of water falls heavily upon the establishments in the Black Hills, because they pay a subsidiary company for that which they use in the batteries, and the item of fuel is likewise a serious one, because their motive power comes from steam obtained from the burning of wood also provided by a subsidiary company. The fuel and water cost amounts to 39 cents, or more than half the entire milling cost. The Californian mills pay for their water at the rates varying from 18 to 20 cents per miner's inch (of 1.574 cubic feet). The Black Hawk mills get their water free from a dirty creek laden with partially oxidized pyrites whose acid corrodes the screens. In winter a diminished water-power is supplemented by steam.

The cost of supplies, mercury, chemicals, lubricants, etc., depends largely upon the distance from a large manufacturing town. It is heaviest in the Black Hills and least in Colorado.

These explanations will now have rendered intelligible the resulting totals, which prove that the mills of Amador do much the cheapest work, and in this respect they are typical of Californian practice, in Calaveras, Tuolumne, Mariposa, Plumas, and other representative districts, more so than Grass Valley, whose millstuff has a quite exceptional hardness. Widening our survey to foreign lands, we note that the three chief gold-mining centers of Victoria exhibit closely approximating averages, while Charters Towers has a high cost because its ores are not amenable to simple treatment, but require an expensive supplement of pans and settlers. The New Zealand districts are similarly related, Otago's ores being simple and docile and those of the Thames complex and refractory. Thus because of complete equipment and cheap motive power the mills of California still retain their pride

VARIATIONS IN STAMP MILLS FOR THE TREATMENT OF GOLD ORES.

Name of district.	Life of screen, days.	Service of screen, tons.	Percentage of concentrates.	Contents of concentrates, ounces.	Retort percentage.	Fineness of bullion, per 1000.	Loss of mercury, dwts.	Consumption of water, gallons.	Description of the ore treated.
UNITED STATES:	(g)		(h)	(k)			(l)		
The Black Hills, S. D.	7	140	*	*	36	815	5	3-3¼	Enormous bodies of gold-bearing schist.
Gilpin County, Col.	60	300	12-15	1-1½	40	780	3½-8	1½-2	Veins rich in pyrites in granitoid gneiss.
Grass Valley, Cal.	18	145	2¼-3	3-5	40	845	9-14	3½-4	Quartz in veins in hard diorite.
Amador County, Cal.	32	380	1-1½	3-4½	45	830	2½-5	3-3½	Lodes of simple quartz in slate.
AUSTRALIA:									
Bendigo, Victoria	11	130	1-2	1½-2½	50	955	7-9	6½-7½	Clean quartz within beds of slate and sandstone.
Ballarat, Victoria	12	140	1-3½	1½-3½	48	970	3-5	5-7	Strong veins penetrating slate and sandstone.
Clunes, Victoria	25	350	1-3	3-4	38	975	‡	8-10	Very simple quartz in veins in slate and sandstone.
Charters Towers, Queensland	5	65	5-25	2-12	35	800	‡	‡	Sulphide ores in veins in syenite.
NEW ZEALAND:									
Otago, South Island	9	70	†	†	40	930	5-8	3½-5	Irregular lodes in quartzose schist.
The Thames, North Island	5½	44	†	†	42	640	12-15	4½-6	Veins of complex ores in andesite breccia.

(g) The acidity of the water and the retention in service of screens that are worn out increase the differences in the life of screens.
(h) That is, percentage of concentrates actually saved.
(k) These are the contents in ounces of gold per ton. The silver contents are generally negligible.
(l) Pennyweights troy. Mercury is sold by avoirdupois.
*Variable. †Not saved. ‡Very variable.

of place as affording the least expensive method of reduction yet devised by man for the obtaining of gold from its ores.

The number of stamps in a mill is ordinarily, but not always, dependent upon the output of the mine behind it. Where the plant is erected upon a flat mill site, 80 stamps, divided into two rows, back to back, makes a very convenient and economical arrangement. Where a graded mill site, upon a hill slope, is chosen, 40 to 60 stamps is a good number. Up to this size there is no proportionate increase in labor costs, but a further enlargement requires a notable augmentation of the force employed. To avoid losses by fire or flood it is, moreover, advisable not to have too many stamps under one roof.

The weight of stamps varies from 500 pounds to twice as much. Only prospecting plants are now provided with stamps of less than 500 pounds, although some old mills are still at work with stamps of 400 to 450 pounds. The light weights in use in the old-fashioned Colorado mill are rendered as effective as the heavier type because of their long drop. The most desirable weight for given ores is dependent, much more than is usually supposed, upon the attainment of conditions favorable to amalgamation. Thus the light stamp (of Gilpin) is the consequence of the long drop, and the long drop is necessary in order to obtain the interval required to permit of the action of gravity in causing the minute particles of gold to separate from the pyrites and settle upon the amalgamated plates placed within the mortar. Where the gold particles readily detach themselves from the quartz or other incasing mineral it is not necessary to emphasize this feature, and heavy quick-dropping stamps are desirable because their greater crushing capacity diminishes the cost per ton.

On the other hand, while the added weight gives greater crushing force to the stamp a practicable limit is soon reached, because the pulverization becomes too rapid for the amalgamation, the ore being reduced so fast that there is not sufficient opportunity given for the gold to be arrested by the mercury on the plates. Steam stamps have for this reason proved unsuitable for gold milling, as was proved by the experiments made by the Homestake Company, described in Chapter VI. The Alaska-Treadwell Company, among others,

carried out a series of experiments and found that a weight of over 1000 pounds made the mill a rapid pulverizer but a poor amalgamator.

The heaviest stamps are usually given to mills designed with iron frames. And, in parentheses, it may be asked why iron frames are not in more general use. At Bendigo and Ballarat such batteries have been pounding away for 30 years past and are yet working sweetly. The supposed weakening of the iron because of the excessive vibration is a bugbear feared by many. A certain simple detail of construction readily prevents any injurious results. Such mills, it may be added, are particularly adapted to the conditions obtaining in some of our Western mining regions, where suitable lumber is becoming scarce at a rate proportioned to the cheapening of iron and steel following upon lessened railroad freights and multiplication of machine shops.

The height of the drop is necessarily proportioned to its rapidity. A high drop needs a long cam, and the endeavor to get speed out of such a combination invariably leads to breakages. Similarly a low drop permits the use of short-armed cams, which lessen the leverage and decrease the strain, allowing of greater speed. A very heavy stamp is not needed with a long drop, nor is it practicable. The fastest work is done by a 750-pound stamp dropping 6½ inches 95 times (with a maximum of 105) per minute; the slowest arrangement is the old Colorado mill with its 550-pound stamp falling a height of 17 inches (and sometimes as much as 20) at the rate of 30 times (occasionally as low as 25) per minute. The divergence of practice in this respect is most assuredly wide enough and furnishes material for a very interesting study.*

The depth of discharge, that is, the distance from the level of the issue (the bottom of the screen) to the top of the die, is a factor whose importance in stamp milling is generally underrated. The deepest discharge is from 14 to 16 inches; the shallowest from nil to 5, with an average of 2 inches. The maximum depth gives conditions which compel slow crushing and a pulverization more minute than the fineness of the screen indicates, because the pulsation of the water

* See Chapter II; also the *Transactions of the American Institute of Mining Engineers*, Vol. XXIII, p. 137, *et seq.*, also p. 569, *et seq.*

inside the mortar is weakened and the force of the issue impaired. The minimum discharge gives only a thin cushion of water between the ore upon the die and the descending stamp; it causes a violent splash and a forceful issue. In the Australian mills there is but rarely any serious effort made to obtain a uniformity in this respect, so that the discharge will usually vary from 1 inch with the new dies to 5 inches as they become worn out. Obviously a difference of 3 or 4 inches causes more variation in the case of a shallow issue than would result from the wearing down of the dies in a deep mortar where the depth of discharge is so great that the increase is only a small fraction of the total. Hence this factor causes more irregularity in the operation of the Colonial and Californian mills than in those of Colorado or Dakota.

In two districts, the Black Hills and Amador, the height of the drop is less than the depth of discharge, which means that in these instances the stamp is never lifted entirely out of the water in the battery. It is doubtful whether this condition seriously impairs the crushing capacity of the mill. It promotes a regular pulsation of the water and pulp such as conduces to regularity of discharge, itself nearly synonymous with rapidity, since not more than a certain amount of pulp can go through the screen apertures at any given time, no matter how violent the splash of the water against them. It does also, I believe, favor conditions helpful to amalgamation, because as against a very violent splash it permits of the settling of the gold particles and minimizes scouring action on the inside plates.

The rate of crushing should not be surprising in the light of the consideration of the different factors which regulate it. One factor, namely, the character of the ore, its composition and its quality, is given in the last column of the table. The possession of very large bodies of extremely low-grade ore is sufficient explanation for the hurried treatment which characterizes the methods of the companies in the Black Hills. The average Californian and Australian mills treat an equal tonnage, and the millstuff supplied by the mines comes from ore depositories of a parallel magnitude. New Zealand comes next, and our old friend, the Gilpin County

mill, is last. And this, too, is not strange, for the mines of its particular habitat are restricted in the extent of their workings and always carry a certain proportion of ore sufficiently rich to warrant direct shipment to the valley smelter. Moreover, it treats an ore which in most districts would be considered hopelessly refractory and is rendered amenable to successful reduction under the stamps by a modification of the ordinary process which, anomalous as it often seems to the uncomprehending visitor from other districts, is yet remarkably adapted to the conditions of the case.

Screens

In the matter of screens there is a perplexing confusion, owing to the loose nomenclature and divergent types of the apparatus employed. The coarsest crushing is done at Clunes, where the practice is to use thick copper plate perforated with only 100 holes per square inch. This lasts during the passage of 350 tons of ore. Since no mercury is put into the mortars of this district, the use of copper is not objectionable on the ground of its liability to amalgamation. Moreover, the coarse sizing of the pulp is permissible on account of the extremely simple character of the millstuff, the gold of which is readily loosened from the fractures and cavities in the quartz. Fine crushing is neither needed nor desirable in preparing such an ore for the blanket tables and wells which form the characteristic gold-saving apparatus of this old mining center.*

The finest pulverization is accomplished by the mills of Gilpin because the intimate association of the gold and pyrites requires such treatment in order to compel a separation. The screens of this district can hardly be considered in the nature of a sizing apparatus; they are made of iron plate punched with alternate burr slots of such a number and size that the chances of a particle of pulp, adequately pulverized, effecting an exit are as 1 in 34. This results in a degree of crushing far in excess of that indicated by the mesh of the screen, because particles once reduced so as to permit of their passage through the openings are thrown back for further comminution. The capacity of the mill suffers, but conditions are obtained suited to the separation of the fine gold from its envelopment of pyrites.†

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* For details of the Clunes practice reference should be made to Chapter VII.

† See also *Transactions American Institute Mining Engineers*, Vol. XXIII, p. 139. *et seq.*

It is a curious fact that in none of the districts quoted in the table are wire screens in the ascendant at the present time. In some instances they have been replaced, within recent years, by punched plate. This seems to me a curious and unfortunate retrogression in milling practice. Nevertheless woven wire cloth is destined to supersede punched or perforated iron plate. Wire screens have apertures approximately equal to the thickness of the wires of which they are made, and therefore offer equal chances for the discharge or retention of such particles of pulp as have been sufficiently crushed, as the discharge area depends upon the relation between the mesh and the thickness of the wire. With a 27 mesh, and a 33 B. W. G. wire they are equal. They give conditions promoting uniformity of pulverization and a high crushing capacity. A recent test made at the Mammoth Mill, in Pinal County, Ariz., showed that as against a No. 6 angle-slot screen and an equivalent wire cloth of 24 mesh and No. 26 wire, the latter crushed 20 per cent. more. They are more liable to be choked by the pulp and weakened by wood chips from the mine timbers, and therefore in well-managed mills we find at least two sets for each battery, so as to permit of a regular substitution pending cleaning or repairing. This is urged against their usage, but surely it is a very foolish economy to sacrifice the proper operation of the mill in the effort to diminish this item of expenditure. The ordinary expense in screens per ton of ore is about 1 cent, so that even the doubling of this is no matter so long as conditions for good work are attained.

The life of the screens depends upon the hardness of the ore, the acidity of the battery water, the attention given to them, etc., but more than these it is chiefly regulated by the length of time which the superintendent considers it desirable to retain them in service. A screen will often actually last without breakage (at the Homestake, for instance) about 20 days, but its openings become so enlarged by abrasion as to permit of coarse crushing to an extent incompatible with successful extraction; therefore it is the practice of good millmen to throw it out after an average, say, of 7 days. This is sensible. False notions of economy cause some men to lose ounces of gold in the effort to save a few cents. In Gilpin

County the enlargement of the screen openings is allowed to go further than is customary elsewhere, and when the screen has had a good service in that part of the mill which is crushing ore from the company's mine, it is transferred for use to the section employed in treating custom ores.

The Thames and Charters Towers districts exhibit the briefest service, because the ores of these regions are rich in the sulphides of base metals whose partial oxidization gives an acidity to the water, causing a corrosion of the iron of the screens. The mills of Black Hawk exhibit a remarkable difference in wear of screens, with a rapid diminution of service as the mills succeed one another down stream, so that from a maximum of three months the average life of a screen dwindles to two weeks. This is due to the fact that the water which has been used in the batteries of one plant is reused in its next neighbor, with a consequent constant increase in acidity due to the decomposition of iron and copper sulphides.

The large percentage of these is indicated in the next column. In some instances the values saved by the mill are so largely in the pyrites collected on the shaking tables that the milling operation becomes more of a concentration than an amalgation process. At Charters Towers the proportion of sulphides is also a heavy one, and the preliminary battery treatment is supplemented by regrinding in pans, followed finally by the chlorination or cyanidation of the richest portion of the concentrates. At the Thames the ores are equally loaded with refractory sulphides, but in that locality no adequate effort is made to prevent them from escaping with the tailings into the sea. The saving of gold remaining in close association with the sulphides is also very inadequately attempted by the Homestake mills. The plant as yet erected for this purpose can only be considered an incompletely planned experiment.* The ores carry from 2 to 5 per cent. of pyrite, pyrrholite, and mispickel.

The principal Australian and Californian gold-milling centers have ores giving an approximately equal percentage of concentrates. Thus we gradate from heavy sulphide ores of a very refractory character, for whose treatment stamp milling is only desirable on account of compulsory local con-

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* See also Chapter VI.

ditions, to millstuff nearly free from admixture with minerals prejudicial to a very complete amalgamation of the gold which it contains.

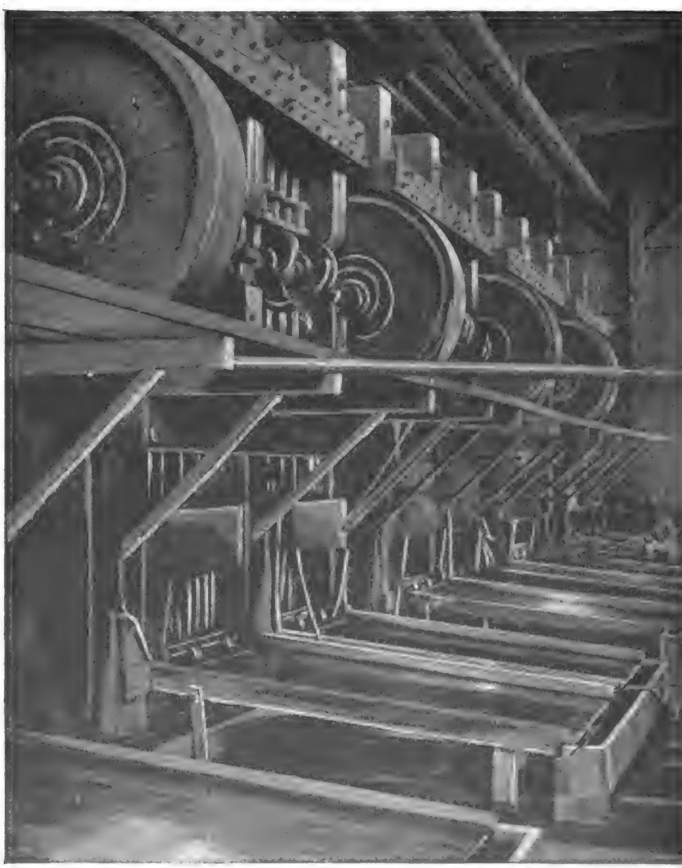
The retort percentage is largely dependent upon the hardness of the millman's hands. Apart from this factor, it becomes proportioned to the coarseness of the gold particles and the thoroughness of their amalgamation—that is, the completeness of the alloying of the two metals, for an amalgam is an alloy formed by mercury with another metal in the cold.

The fineness of the bullion is an excellent index of the docility of the ores, because those which carry their gold within an incasement of pyrite yield retorts containing impurities, of which silver is the most frequent and least undesirable. It certainly does so happen that if you go through the list of these milling centers, taking them in the order of their bullion fineness, beginning with Clunes (975 per 1000) and ending with the Thames (640 per 1000), you will have the exact scale of their gradation from the most distinctly free-milling, docile ore to the most decidedly difficult and refractory. Furthermore, speaking generally, I may mention, as a striking coincidence merely, that this figure will be roughly indicative of the percentage of extraction, because this last is a corollary from the fact just noted. Thus a Gilpin County mill will extract just about 78 per cent., those of the Thames rarely reach 64 per cent., those of Grass Valley usually exceed 84 per cent. As a rough approximation of a probable extraction, the fineness of the retort gold affords in this way an interesting guide.

The variation in mercury consumption is the widest of all, from 5 grains to a pound per ton. The minimum figure at Clunes is traceable to the fact that no mercury is used in the mortar and blanket tables replace the copper plates ordinarily employed on the outside. Mercury is only used in wells and in the barrel which treats the blanketings. Rich ores entail a greater consumption than poor because more mercury is used. Charters Towers and the Thames give the maximum loss because of the addition of mercury in the pans, where it becomes floured and sickened* by being present while base sulphides are undergoing grinding.

* See Chapter XV.

Water consumption is primarily dependent upon the rate of crushing. It is increased by the addition of processes supplementary to the ordinary battery treatment. Blankets require more water than plates, hence the high figure at Clunes. Slow crushing needs a small supply, therefore the low consumption in Gilpin.



The Elmore Mill, Rocky Bar, Idaho.

Finally we reach that most important factor of all, the character of the ore. It is a cynical truism to say that the milling process should be adapted to the nature of the ore, because, unfortunately, it reminds one at once of the scores of expensive plants which are rotting upon the hillsides of our

mining regions as the consequence of a perverse disregard of this obvious relation. Ordinarily it is best to have a mine possessing certain ore reserves before starting to erect a mill. Moreover, it is safer to have representative lots of ore tested at a neighboring reduction plant than to design a line of treatment on the insecure basis of a few laboratory experiments. The old folly still survives. Men of intelligence try a few grains of ore in a test-tube and then hasten to telegraph the order for a $50,000 mill. English directors are particularly prone to placing blank orders for "a gold mill" in the hands of fashionable machinery firms. Many of the resultant failures are put upon the broad back of an old well-tried process, which is further loaded with the incubus of incompetent management and incomplete equipment. The average mine-owner not infrequently prefers fooling with "a man and a process" to spending a thousand dollars in properly directed experiments. Consequently there are many who, complaining of the unsatisfactory extraction in the batteries of a badly arranged or incompletely equipped stamp mill, rush headlong into the maze of complicated, half-understood leaching processes. Their last end is often worse than their first.

In the above list of gold-mining centers there are at least two, both colonial, instances of the application of stamp milling to ores essentially unsuited to such a process of reduction. Some one put up a stamp mill long ago and the others have copied the first builder, because probably the ores that went to that first mill were so rich that in spite of an unsatisfactory percentage of extraction the mine paid dividends. After that no one wanted to be guilty of unprejudiced investigations resulting in a new departure. In other instances, as in Gilpin County, while the ores of most of the mines and most of the ores of any particular mine are susceptible of successful treatment by the process in vogue, there is much millstuff undergoing amalgamation and supplementary concentration which should be subjected to well-devised concentration accompanied by incidental amalgamation. This is being realized of late, so that the stamp mill, the concentrator, and the smelter in the valley will each receive that proportion of the ore production which is clearly designed, from a metallurgical standpoint, to go to them.

Incidentally mention may be made of the use of the stamp mill for the recrushing of the tailings from jigs. It has been generally supposed that jig sands are not suited to battery treatment. Their regrinding has been given over to rolls, Huntingdon mills, and a multitude of patent pulverizers. The successful work accomplished at several mills in the southwestern part of Colorado has shown that both the Huntingdon mill and the stamps are well adapted for this purpose; that the former is, because of its construction, suited for erection in mountainous regions; and that the stamp mill will treat jig sands satisfactorily when due regard is paid to regular feeding. Under such conditions it has a capacity and gives results rendering it suitable for such tailings coming from the jigs as consist of quartz sands containing free gold and have been previously deprived of those brittle sulphides which make slime. The crushing of ore preparatory to jigging is, on the contrary, a work which it is rarely advisable to give to the stamps, because, being badly adapted to sizing the pulp, they deliver it in a poor condition for concentration.

Certain districts in both hemispheres make only a lame effort to arrest the gold-bearing sulphides escaping in the tailings of the stamp mill. The ordinary practice is to employ two vanners per battery, because it is the ratio which has been found adequate to the treatment of the ores of the Californian mines, where the vanner first came into successful use. Guided by such a venerable rule of thumb, the millowner equips his place in a stereotyped fashion, regardless of the fact that his ore may carry a several times larger percentage of sulphides. As a rule, the number of vanners is insufficient because it is not recognized that they are machines which to do close work cannot be crowded. Nor, on the other hand, should it be expected that a delicate concentrator such as this can give satisfactory results when called upon to treat pulp varying in size from 30 mesh to impalpable slime. The importance of sizing, itself an inexpensive operation, is almost universally overlooked in English-speaking countries, to the heavy detriment of the work done by vanners and shaking tables.

The successful introduction of certain leaching processes, whether for the reduction of concentrates or the treatment of

tailings, has caused many millmen to lose sight of the desirability of extracting the values in the ore as soon as possible and not expecting to redress the unsatisfactory results of a poor battery amalgamation by a subsequent supplementary process. The pride of many millmen over the obtaining of gold from tailings which have been permitted to go through the mill without yielding up a proper percentage of their contents, and the satisfaction expressed over the work afterward done by the cyanide tanks or the chlorination vats, is due to a disregard of one of the first postulates of good milling, namely, to catch the gold as soon as possible. Do not send specimen ore to the battery if it can be treated in a hand mortar; do not let the gold get into the outside plates if it can be arrested within the battery itself; get it on the amalgamating tables rather than on your blankets or in your wells; do not depend on your concentrators if you can save the values by amalgamation, nor neglect the care of the vanners because the tailings are to undergo further treatment. A sportsman is not considered a good shot because he misses the bird with his first barrel and brings it down with the second.

In the foregoing glance over the field of activity covered by the simple mechanism of the stamp mill, the Witwatersrand has not been included because the practice of that region is yet in its formative stage and is destined to undergo important changes of development. At present it offers a magnificent opportunity for the utilization of the best experience of the older districts of the world. The application of the stamp mill to the conglomerates of the Rand serves further to accentuate its wide range of usefulness. It is this adaptability to ores of great diversity which enables it to hold its own in the face of the newer devices constantly offered by the restless inventive genius of the age. Between a simple white quartz carrying loosely attached particles of coarse, clean gold and a compact pyrite wherein the gold is invisibly enveloped, there is a divergence so great as to emphasize the elasticity of a process which, despite the encroachments of the smelter on the one hand and wet methods on the other, remains the simplest and cheapest way of extracting gold as yet devised by the ingenuity of man.

CHAPTER XVII.

Mills and Millmen.

In looking back over the visits to so many mills in localities so essentially unlike it is impossible not to realize that the variations in milling are as nothing compared to the variations in mankind. The gathering of data by means of inquiry and observation is an undertaking the pleasure of which is too often swamped by the labor consequent upon the drawing out of information from persons unwilling or unable to give it. Much as technical science has made itself at home in every Anglo-Saxon community, there yet remain many who cannot comprehend the gathering of knowledge for its own sake, and only too often the inquirer is received with a suspicion which is as annoying as it is detrimental to the objects of his pursuit. In gathering data at the various milling plants I have found, as a rule, that the establishments which were the most systematically conducted were the readiest to grant the information required; that the most refractory were the most ignorant of what they were really doing, and that in the latter case frequently the questions asked were such as the mill manager himself had never put to himself, and to which therefore he could not reply without realizing, and for the first time, what he actually was doing.

The differences between the abilities of millmen and the management of mills would be absurd were it not depressing. It is depressing because there seems to me to be no excuse for consigning the handling of an ore-reduction establishment to the hands of a carpenter or a miner; it is depressing because it appears such a blunder to exercise all skill and judgment in the mining of the ore and then to overlook the importance of the subsequent proper extraction of its valuable contents.

That such things should be is due to the fact that the stamp mill is usually considered a very simple mechanism, capable of regulation by almost anyone. The apparent simplicity of the treatment has prevented technical men from making it the subject of study which it appears to the writer to fully deserve and invite. And this the more since, in spite of the encroachment of other more intricate processes, the stamp mill seems to be destined to a career of further long-continued usefulness.

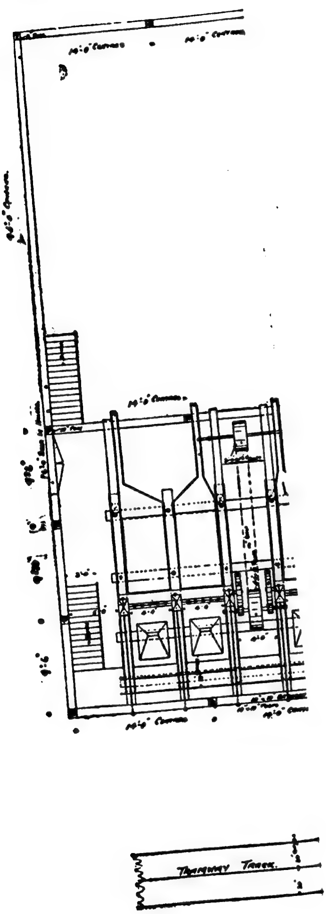
It is, indeed, true that fire-reduction processes are encroaching on wet methods, more particularly in the case of complex ores; it is also true *per contra* that chlorination, cyanidation, and other leaching processes, are actively competing for the millstuff which might otherwise go to the battery, yet it will generally be found that the diversion to other reduction works of ores suitable to stamp milling is comparatively slight and confined to such as are essentially unadaped for amalgamation.

The simplicity of the machinery of stamp milling, its long-proven adaptability to various docile ores, and the noteworthy cheapness of the treatment, render it preëminent among metallurgical methods of gold extraction. We hear continually of new inventions for the rapid pulverization of ore and the easy extraction of its contained gold. New processes are born daily but their mortality is very depressing. It may be that some heaven-sent revelation may some day enable the metallurgist to extract 100 per cent. of the value in an ore at a cost insignificant when compared to the magnitude of the result, but we may well have grave doubts. The story of metallurgical progress proves it to have been evolutionary and not revolutionary. It is by the gradual improvement of established methods rather than by the sudden application of new and untried processes that success is soonest attained and longest maintained. The record of the chlorination process in America affords an instructive illustration. Although employed at Grass Valley, Cal., as early as 1857, it has taken nearly 40 years to bring the knowledge of the best methods of its application to such a stage as to render its use technically successful and economically safe. From the slow and simple practice first borrowed from Plattner it has passed through many changes until to-day in the improved barrel

process it has taken a firm hold upon a certain part of the metallurgical field. Cyanidation, on the other hand, illustrates in a marked manner the earlier struggles of all leaching methods, and its checkered career is one commonly shared by delicate chemical processes of ore reduction in course of successful evolution from uncertain beginnings.

The more familiar methods of stamp milling have long ago grown out of the uncertainties of early development. How gradual and how great that development has been, can only be realized by tracing the workings of human ingenuity through many centuries of endeavor from the first conception of the simple savage with his stone implement to the completed mechanism of the modern millwright. It is a story of the survival of that which was fittest for the work of extracting that gold which has ever been the *ignis fatuus* of humankind; it is a tale of the adaptation of methods to different environments, which have included within their limits the arid deserts of Western Australia and the snow-clad summits of Colorado. The inquiry into the divergent practice of scattered regions has indicated clearly that the key to the apparent contradiction involved in methods which seemed so opposed in principle, is to be found in an earnest attempt to adapt methods to local conditions. The real principles—the bedrock ideas—of stamp milling are unchanging, but their successful application has created a growth of local variations which are discordant only when viewed without due consideration to diverse conditions.

No method of ore reduction is perfect; the metallurgist cannot dare to consider any particular process the *ultima Thule* of technical progress, and in spite of the long period of development through which the stamp mill has passed it needs no hesitation to assert that no milling plant exists which is perfect. It is hardly necessary to add that in the course of inspecting more than a hundred mills the writer has frequently met with those who considered their own plant impossible of improvement. The worst of all ignorance is the ignorance of our ignorance. The most experienced millman is usually very well aware that the improvements made in the past are merely the measure of the betterment attainable in the future.



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Tail plates

Engineering is applied common sense; and we do not wonder to find that many of the alterations which render the mechanism of to-day superior to the rude appliance of yesterday, are striking more for their ingenious utilization of simple principles than in their embodiment of complex considerations. If I should pick out any part of the stamp mill as more particularly illustrative of this truism, I would select the amalgamating table. Everywhere the sloping surface of copper plate or the outspread stretch of blanket serves as a gold-saving appliance to supplement the variously successful extraction in the mortar box. The amalgamating tables are generally arranged in two series, of which the upper one, called the apron, has a width approximately equal to that of the issue of the battery, and varies only between narrow limits, from 4 feet 4 inches to 6 feet. Its length shows greater extremes, reaching from 2 or 3 feet to as much as 16 feet. Then comes the lower table, also termed the sluice or tail-plate, which rarely is of a size equal to the apron, but more ordinarily, especially in California, has a width of about 20 inches, and a length of from 10 to 20 feet.

The arrangement of these obviously very important parts of the gold-saving appliances of a stamp mill usually invites condemnatory criticism; sometimes even cynical derision. For what, I would ask, can be more absurd than to pass the pulp over a surface 5 feet wide, extracting some of the coarse gold, and then to compel it to run within the confined width of 20 inches in the expectation of arresting gold less coarse, and, therefore, more difficult to arrest, than that which has been caught above? It ought to be obvious to ordinary common sense that the gold to be saved below the apron is of a kind which, because it has escaped the first effort to catch it, is necessarily more elusive than that previously saved, and that therefore conditions more favorable to its arrest than those obtained on the apron-plate are required. The common actual practice would point to the contrary view, since, after the pulp has slowly washed in successive waves over the wide surface of the upper table, it is rushed through the narrowed confines of the lower. In several instances, moreover, I have actually found the sluice-plate to slope at a steeper angle than

the apron, with the result that the edges of the copper surface were scoured and their amalgam rubbed off by the rapid flow of sand and water.

What is evidently needed is a reversal of the ordinary method; the spreading of the pulp over an area of increasing width rather than its confinement within a narrowing space, such as makes the ordinary sluice much more of a launder for the rapid conveyance of the pulp than a device for the saving of any gold which may pass over it.

When traced back through the years it will be found that the use of this quite absurd arrangement sprang from the fact that it was borrowed from the placer miner, and that it originally formed a part of the alluvial diggers' gold-saving apparatus. River mining preceded vein mining, and in transferring his energies from the one to the other the miner was inclined to use as much as possible of the plant needed in the one industry for employment in the other. The sluice-plate in the mill is a modified form of the sluice-box of the gulch.

Notwithstanding the marked improvement made in the mechanical appliances of the typical western American stamp mill, tending chiefly to greater automatism of treatment, this particular feature remains a blemish and a defect for which there is no excuse save that "everlasting monkey" in man, in virtue of which the millman copies the methods of his neighbor without proper investigation into its merits or intention. No part of the apparatus of the mill is so cheap as the amalgamating plate. An old plate is always worth more than a new one, because of the gold which it absorbs in process of use. The fact that the bottom of a plate catches any amalgam, in amount however small, should be sufficient evidence that some is escaping which could be arrested by a further elongation or enlargement of the amalgamated surface. I have never seen a mill which had too much plate area; I have seen several which had too little. And in this connection I may be pardoned for mentioning the fact that in two instances where I have been called upon to endeavor to suggest means for an improvement in the gold extraction of a stamp mill, I have succeeded to a notable degree in doing so by the simple rearrangement or extension of the amalgamated copper plates.

No completeness of treatment is likely where no accurate knowledge of the results is secured. In most stamp mills accurate and systematic sampling is unknown. The estimation of the percentage of extraction is usually mere guesswork based on an occasional assay of a sample carelessly taken. As I write I remember only three instances of proper care in this department. They were the Harrietville mill (Australia) and the Empire and North Star mills (California). Establishments of such a magnitude as the Homestake in South Dakota merit condemnation for an absence of proper system in this regard. Too many millmen are in utter ignorance of the real character of the results which they are obtaining, an ignorance which is as consolatory to a complacent self-satisfaction as it is injurious to the real interests of the proprietors of the mill.

It is impossible to become familiar with the work being done at stamp mills scattered the wide world over without being impressed with the frequent waste of time and money incurred in the carrying out of experiments at one locality which have been made long previous in some other district. You may, for instance, find the mills of one region introducing for the first time a form of tappet which was thoroughly tested and found altogether undesirable at some other place a few years previous; or a millman in Australia may be designing a mortar to do certain work and of a pattern practically identical with one which was tried and found unsuitable in California a decade ago. The waste of experience, the going over ground a second time which has once been proven, the failure to use the results of careful tests made by others, this presents a subject which must often have impressed and saddened those who have investigated the struggles and endeavors which have been the stepping-stones to metallurgical development.

There is a curious lack of intercommunication between those who direct the operation of mines and mills in various parts of the world. Although this is overcome in some instances by the reading of *The Engineering and Mining Journal*, the *Transactions of the American Institute of Mining Engineers*, etc., it nevertheless forms a serious bar to intelligent advancement. At many of the largest milling establish-

ments you may find men in charge who are even proud of never having stirred from their own locality for a period which covers 10 or 20 years, and may sometimes reach a lifetime. The world is moving; technical progress has made strides which have stamped our modern civilization with characteristics unknown to previous history. Is it not lamentable that men should stick in the mud in their own little hamlet, careless of what others may be doing, heedless of opportunities for improvement, because their minds are dulled by a sleepy belief that the workings of their own little practice is incapable of betterment?

Rhetoric apart, and in all seriousness, would it not prove profitable to many large proprietaries, on both sides of the equator, if they would occasionally send their captains of industry to investigate the methods of other regions, to see and to study and possibly imitate, the results of experiments and improvements made by others in their own line of work?

There is reason to deplore the general rarity of careful investigation. The choice of screens, the use of certain chemicals, the employment of different metals for shoes and dies, matters such as these are ordinarily determined at haphazard, or by the ancient and venerable rule of thumb. Occasionally tests are made, but of such the majority are hopelessly vitiated by want of system and lack of accuracy. A man, for example, tries to find out which kind of screen to employ, so he fits up one battery with the one and the next battery with the other. He forgets that owing to the disposition of the rock-breaker one battery gets more of the fines than the other; he omits to note that in one mortar the dies are worn down and in the other they have been lately replaced, so that the issue in the two batteries differs by a couple of inches. A test under such circumstances is a snare and a delusion. The ordinary result is a mass of contradictory data which are only helplessly confusing.

There is a common repugnance among millmen to do any experimenting. This springs largely from the known futility of previous tests which were inconclusive because carried out under unequal conditions. For such a feeling those are to blame who, imperfectly understanding what they were about, directed work whose object their subordinates failed to

appreciate. The average millman may be stubbornly opposed to the trying of new methods which are only partially comprehended by those advocating them, but he is, I believe, fair-minded enough to be willing to carry out tests which are based on an adequate comprehension of the conditions of the case.

On the other hand, careful tests made to determine a certain factor in the milling problem, when they are made under equal conditions, such as guarantee reliable results, are invaluable. In every mill there should be a reason for doing anything in a particular way. The millman should be able to show cause for having the height of drop just what it is; he should be in a position to explain why he cannot recommend a depth of discharge a couple of inches more or less than that actually in use, and so on. If uncertain why particular methods are in vogue he should by accurate experiment, as soon as circumstances permit, confirm their correctness, or replace them by others which he finds better. The practice of guessing twice and then dividing by two for further accuracy is one which can only conduct a man into a hopeless bewilderment between what he does know and what he thinks he knows.

CHAPTER XVIII.

The Future of the Stamp Mill.

The stamp mill has suffered much in repute from the frequent failure to adapt the design of the mill to the capacity of the mine or the character of the ore. Some men order a reduction plant like others order a dinner. They go to the representative of a well-known machinery firm and tell him about the mine and the nature of the ore, and then leave the choice of the arrangement of the mill to him just as a man might enter a first-class restaurant and tell the head waiter to serve a good dinner, leaving the menu to his judgment. Mine-owners often hate to expend a thousand dollars in advice or experiment previous to the erection of an ore-reduction establishment, but really enjoy ordering a hundred-thousand-dollar mill, which may no sooner be completed and at work before they find that the process is unsuitable or the ore supply inadequate. Hence the frequent monuments to folly which dot our western hillsides. *Hinc illæ lacrimæ* when shareholders inveigh against processes which prove a delusion and mills that fail to yield dividends. The causes underlying the miscarriage of milling plants are not obscure. If they are hidden from the unwise and imprudent, they are daily revealed to mere babes in metallurgical experience.

Only recently a typical instance came across my way. A mine-owner, who is ordinarily a real estate broker, went to the manager of a machinery manufacturing concern and, exhibiting a piece of ore, told him that he wanted a mill to treat material of which that is a sample. The ore carried a large percentage of pyrites, but the gold associated with it, so said the real estate broker, was entirely amalgamable. The machinery man advised him to put up a long-drop, slow-

speed stamp mill, supplemented by concentrating tables. It was so ordered. The mill was shipped in due time, and was erected in the wilds of Idaho. From the very start everything went wrong. The mill did bad work, and the mine-owner anathematized the machinery fellow; the latter excommunicated the former. Not long afterward I happened to be on the ground and found the facts to be simple. When the mill was ready to start it was fed, not with the hard pyritic quartz such as the original sample shown, but with very soft surface gossan. The feeding was low. The stamps with their long, slow drop came crashing through the thin cover of soft material. Cams began to break, shoes went into splinters, and screens were destroyed in a day. The mill was overhauled, the drop was shortened, and the cams replaced by others. The arrangement of the mill was gradually so modified that it became a hybrid between a short-drop, quick-speed form of battery and its original design. Better results were obtained. Then a new superintendent came upon the scene. Work at the mine was transferred from the surface open cuts to deeper levels. Hard pyritic ore was sent to the mill. The crushing capacity of the stamps was diminished, and the amalgamating tables, their slope remaining unchanged, were unable to clear themselves. Extraction declined out of sight. The machinery firm was again pilloried. About this time the undertaking got into financial trouble and the plant was hired by a neighboring company, which was able to treat its (similar) surface ores in this mill with marked success. It all sounds foolish enough, but pity 'tis 'tis true, and not once only, but many times.

The machinery man, however, often deserves censure also. There are establishments which have what they call a "standard" type of mill which they highly recommend for the reduction of ore running through a whole gamut of differing composition. Like the iron bed of Procrustes, to which the wayfarer had to suit his length at the risk of summary abbreviation or painful elongation, so the manufacturer expects the ore to adapt itself to his mill or choose between being labeled unprofitable or refractory. These are difficulties which could be readily overcome. The failure of a plant hurts the reputation of the firm that supplied it no less than

it decreases the value of the mine. It would be a profitable thing for both parties in the transaction if, it being agreed that the order will be placed, they could agree upon an investigation of the ore by a competent authority with a view to determining the best treatment, the expense of such investigation to be divided between them.

More than once, in the course of the investigations upon which these studies of milling have been based, there has come the question, Is the stamp mill likely to survive amid the inventions daily heralded from the Patent Office? Will it continue to compete successfully with the multitudinous pulverizers and amalgamators, together with the unending array of new processes which the restless brain of man brings forth from day to day? To the writer, looking over the field of metallurgical competition and cognizant of the fearful slaughter that befalls the army of ill-conceived and half-completed machines which their inventors fondly imagine competent to revolutionize ore reduction, there comes a strong belief that the stamp mill is destined to survive amid much competition and to enjoy a career of further long-continued usefulness. Often enough some other process or some different pulverizing mechanism is claimed to do better work than the stamp mill. Occasionally this is true for particular ores under particular conditions, but just as frequently it is due to the fact that in making the test the stamp mill has been of unsuitable design or has been unintelligently handled, so that the comparison has been unfairly made. There is, believe me, just as much difference between a model stamp mill properly directed and an imperfect one badly managed as there is between the latter and some one or other of the newer processes of ore reduction. I have known a leaching process put in rivalry with an imperfectly equipped or improperly managed stamp mill, and the former has given a percentage of extraction greater than the latter, but in the sequel it has become evident that the stamp mill, when it has been subsequently provided with the needed appliances and superintended by the necessary man, has surpassed the leaching process as much as the last previously surpassed the stamp mill.

One feature of the stamp mill stands out clearly when instituting a comparison between it and other pulverizers, namely, it is a crushing and an amalgamating, a reducing and an extracting machine combined. This distinctive feature has enabled it to hold its own against other newer inventions for pulverizing ore and to meet the fierce competition of so many more complete and more complicated amalgamating machines. In the two extreme types of the stamp mill, so often referred to, we have seen, on the one hand,* how an increased degree of amalgamation has been secured at a sacrifice to rapidity of pulverization, and, on the other hand,† how fast crushing has been aimed at and battery amalgamation made subservient to the desire for the expeditious treatment of large quantities of low-grade millstuff. In the one case the mortar has been enabled to do work otherwise beyond its scope; in the other, ore has been handled with commercial success which otherwise could not be profitably reduced. It is interesting to note, however, that even in California and South Dakota, where the stamp mill is so designed as to be essentially a rapid pulverizer, the amount of gold arrested inside the mortar forms about one-half of the total extraction.

This feature of the stamp mill is one overlooked by many who daily direct their inventive genius to the discovery of a mechanism which shall surpass the clumsy contrivance whose reverberations echo from Coolgardie to Colorado. The steam stamp, for instance, eminently successful as it has shown itself in the quick reduction of the copper ores of the Lake Superior region, has not proved satisfactory in its application to gold ores. Why? Its crushing capacity per horse-power consumed is much ahead of the ordinary stamps. True, but it does not permit of amalgamation going hand in hand with pulverization, the force and rapidity of the discharge are unfavorable to fine crushing, the extreme violence of the agitation inside the mortar prevents the introduction of amalgamating plates, and, as a whole, it notably fails in giving the conditions required for successful milling.

The same question crops up in the discussion of the use of heavy stamps. The Alaska Treadwell Company made numer-

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* In Gilpin County, Colorado.

† In South Dakota and California.

ous experiments, and found 1000 pounds the practicable limit. Heavier stamps might crush faster, and indeed did so, but this very fact resulted in the rushing of the ore through the battery so rapidly that opportunities for that contact between the gold and the mercury which is the essential requirement for amalgamation, were lessened to such an extent as to seriously diminish the percentage of extraction. The mill became a good pulverizer, but a bad amalgamator.

Nine-tenths of the patent pulverizers and new amalgamators thrust before the public through the medium of bombastic advertisements are crippled by a similar defect. Where rapid pulverization is secured an ineffectual effort is often made to secure concomitant amalgamation, but in most cases the cutting up of the mercury introduced into the machine causes so much "flouring" as to render a heavy loss of both mercury and gold unavoidable. I have before me, as I write, a typical description of a machine of this kind. The author of the description, who possesses merely a bowing acquaintance with his subject, emphasizes the statement that it is an "evolutionary machine" which for the first time utilizes a new principle, namely, the "atomic pulverization" of the quartz and the complete liberation of the gold. I happen to know that that "evolutionary machine" lies resting in many a mill where it can now be purchased on the basis of scrap iron. Let me mention another example. Lately, while going up one of our picturesque Colorado cañons, I visited a plant which has been rearranged. The man in charge informed me, with unnecessary emphasis, that mercury was a "robber of gold," and that his (the speaker's) "new system," which was to utilize "hot water and air," would plainly demonstrate such to be the fact. I enjoyed the subsequent conversation. That man was as deliciously ignorant of what the stamp mill can do and how it does it as the dog that bays at the moon is of astronomy. He had persuaded a few stockbrokers to introduce his "new system," of which what was useful was as old as the hills, and what was essentially absurd and impracticable was his, entirely his. Such instances are not uncommon. They happen weekly in spite of frequent doses of bitter experience. They explain why so many mills are

rotting in the sun and rusting in the rain—object lessons whose teaching is as unheeded as the whistling of the wind through the neighboring pines.

Not that one would suggest that mechanical ingenuity and metallurgical experience will fail to better our present methods. No; but that betterment will be brought about by men who are cognizant of what is being done already and of how the present practice was evolved rather than by those who are contemptuous of a process whose principles and application they have scarcely tried to comprehend.

Therefore, in conclusion, to millmen and metallurgists, fellow-students in a field of endless interest, I would say: Let us endeavor to use the stamp mill intelligently, to understand the why and wherefore of every one of its successive operations, and to lose no opportunity of applying any contrivance or modification which experience sanctions and experiment corroborates. That done, we shall have done our little best as best we can. In the meantime the inventive genius of this great mechanical age ruminates apart in an earnest effort destined in due time to evolve something better wherewith to catch the yellow gold whose want is the pain of some, whose excess is the curse of others.

A GLOSSARY OF STAMP-MILLING TERMS.

In the following explanation of the terms which have been used in these articles the first word will be American and the second the English or Australian equivalent. The American terms are often used outside of the United States.

Stem or shank.—The vertical rod or shaft of wrought iron which carries the stamp at its lower end. It is the handle of the hammer.

Boss or tophead.—A heavy cylindrical piece of iron (usually cast or steel) into the top of which the stem fits and into the bottom of which the shoe is inserted. It is the body of the hammer into which the handle fits and which also gives heft to the blow.

Shoe or head.—The wearing part of the stamp which comes in contact with the ore and does the actual crushing. The hammer-head.

Die or false bottom.—The iron, a flat hexagonal or cylindrical piece, upon which the ore is crushed. It is the anvil. At Clunes, in Victoria, it is called the "stamper bed."

Cam or wiper.—The curved lever which lifts the stamp and is therefore sometimes called the "lifter."

Tappet or Disc.—The collar under which the cam is inserted so as to lift the stamp.

Mortar or coffer.—The box, sometimes of wood but lined with iron, usually solid cast iron, inside which the operation of crushing takes place. It is the mortar of which the stamp is the pestle. Also called "stamper box."

Screen or grating.—The perforated metallic plate or wire cloth through whose openings the crushed ore is discharged, and which is intended to prevent its exit until crushed to a degree of fineness supposed to be regulated by the number and size of the openings in the screen.

Ties and tyes.—The latter to be preferred. A Cornish term for the sluice-boxes used for the extraction of the heavy sands in mill tailings.

Tailings.—The waste from the mill; the pulp after the gold has been extracted by mill treatment. In Gilpin County, Colorado, it is applied, erroneously, to the concentrates saved on shaking tables.

Chuck-block and chock-block.—The first to be preferred. The

wooden block or board which is attached to the bottom of the screen so as to raise the depth of the issue and act as a false lip to the mortar.

Discharge or issue.—The expulsion of the pulp from the mortar. It is also used to designate the distance from the bottom of the screen to the top of the die, because this figure determines, more than any other factor, the rapidity of the expulsion of the pulp.

Battery.—Any single mortar with its stamps (usually five) complete. The words "stamper" and "head" are also employed in the colonies in place of "stamp."

Mill or machine.—The latter is largely confined to Queensland, although "crushing machine" and "battery" are used synonymously with "mill" in other parts of Australia to designate the reduction plant as a whole.

Traps or wells.—The troughs and catch-pits, whether carrying mercury or not, which are used to arrest escaping amalgam, etc. The word "trap" should be confined to the deep boxes unprovided with mercury, and the word "well" to the transverse troughs which do contain it. At Clunes the word "boxes" is used, while elsewhere in Australia "ripples" is a term given to shallow wells as distinguished from the deep ones.

Pan or dish.—A copper or galvanized iron utensil used for washing gold ore and gravel so as to separate the heavy gold by a shaking motion. It corresponds to the Cornishman's vanning shovel.

The Australian uses the word "crushing" where the American says "mill-run" to designate the treatment of a given quantity of ore. The Colonial employs "mullock tip" and "spoil heap" as synonymous with the American "dump" to describe the accumulation of waste rock coming out of the mine.

The American prefers "quicksilver" where the Australian uses "mercury." In the Colonies a "flask" of mercury contains 75 pounds avoirdupois and in the United States a "bottle" or "tank" of quicksilver contains 76½ pounds. The Colonial calls the ore sent to the mill "stone," the Englishman "millstuff" and the Colorado-Cornishman "mill dirt."

The growth of travel and the rapidity of modern methods of communication tend to bring about a uniformity in technical terms which is convenient and desirable.

INDEX.

Aprons 239

kind

Stamps - Revolution of 94

Sluices 239